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Prepared in the Division of Publications,
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 776

Contribution from the Bureau of Markets,
CHARLES J. BRAND, Chief.

Washington, D. C. March, 1919.

COLD STORAGE REPORTS, SEASON 1917-1918.

APPLES, BUTTER, AMERICAN CHEESE, EGGS, AND POULTRY.

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Assistant in Market Surveys.

CONTENTS.

INTRODUCTION.

THIS BULLETIN is the second of a series of reviews of the storage reports of the Bureau of Markets. The first of the series was published as U. S. Department of Agriculture Bulletin 709, entitled "Reports of Storage Holdings." It gave a summary of the work of the Bureau up to January 1, 1918, and reviewed the cold storage season of 1916-1917 for apples, butter, American cheese and case eggs. It also reviewed the previous year's reports on the storage holdings of frozen and cured meats. The present bulletin reviews the season of 1917-1918 for apples, creamery butter, packing stock butter, American cheese, case eggs, frozen eggs and frozen poultry. The storage holdings of frozen fish and frozen and cured meats during 1918 will be reviewed in a separate bulletin which will be issued as soon as possible.

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF APPLES.

The first report of the 1917-1918 season showing the holdings of apples in cold storage was issued for October 15, 1917. The total holdings as reported by 467 cold storage warehouses amounted to 1,106,977 barrels and 1,178,215 boxes. This was 7.1 per cent less than the amount stored on the same date of the previous season. If we consider three boxes the equivalent of one barrel it will be observed that 75% of the stock in storage at this time was packed in barrels. On October 1, 41.3 per cent of the barreled apples had been stored; 36.8 per cent were stored during the latter half of October; 17.8 per cent during the first half of November and 4.1 per cent during the last half. The storing of the barreled apples was practically completed by December 1, when the total holdings amounted to 3,368,251 barrels.

The movement of boxed apples into cold storage was much slower and extended until January 1. The holdings on October 15 represented only 24.2 per cent of the total amount stored; 18.4 per cent went into storage during the latter half of October; 45.5 per cent during November; and 11.9 per cent during December. The holdings of boxed apples in the great producing section of the Northwest, however, reached the highest point on December 1, thus showing the large percentage that was shipped to Eastern storages and the delay in shipping owing to transportation difficulties. All other sections showed the largest quantities in storage on January 1.

Table 1.—Cold storage holdings of apples at the peak load of the 1917-1918 season.

Section.	Barreled apples.			Boxed apples.			Combined in barrels.		
	Storages reporting.	Total holdings.	Percentage of total holdings.	Storages reporting.	Total holdings.	Percentage of total holdings.	Storages reporting.	Total holdings.	Percentage of total holdings.
	Number.	Barrels.	Per cent.	Number.	Boxes.	Per cent.	Number.	Barrels.	Per cent.
New England	25	162,225	4.8	19	61,160	1.0	27	182,612	3.4
Middle Atlantic	124	829,538	24.7	66	1,071,474	18.4	124	1,186,696	22.4
South Atlantic	59	819,765	24.3	45	108,731	1.9	60	856,009	16.1
North Central (E)	110	839,207	24.9	79	905,508	15.6	112	1,141,043	21.5
North Central (W)	84	475,639	14.1	92	749,015	12.9	92	725,311	13.7
South Central	53	241,836	7.2	78	520,220	9.0	78	415,242	7.8
Western (N)	3	0	0	39	1,171,599	20.2	40	390,533	7.4
Western (S)	2	41	0	39	1,219,736	21.0	41	406,619	7.7
Total	460	3,368,251	100.0	457	5,807,443	100.0	574	5,304,065	100.0

Table 1 shows the boxed apple holdings of January 1 and the barreled apple holdings of December 1 segregated by sections and also the boxed apple holdings of January 1 reduced to barrels and combined with the barreled apple holdings of December 1. This shows a total of 5,304,065 barrels, representing the peak load of the 1917-1918 season and approximately all apples placed in cold storage during the season.

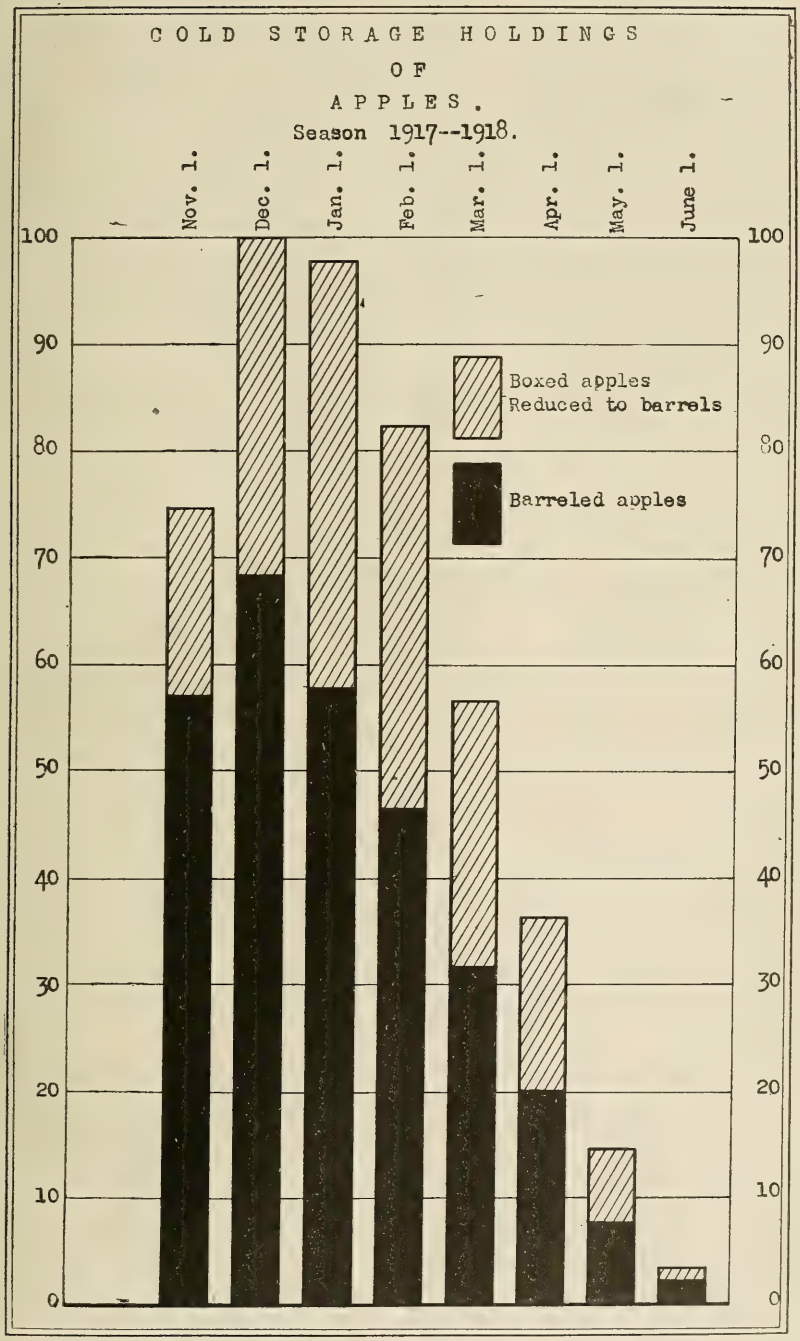
COLD STORAGE HOLDINGS
OF
APPLES.
Season 1917--1918.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
Apr. 1.
May. 1.
June 1.
100
90
80
70
60
50
40
30
20
10
0
Boxed apples
Reduced to barrels
Barreled apples

Fig. 1.

The Bureau of Crop Estimates estimated the total season's crop of apples to be 58,203,000 barrels and the commercial crop to be 20,959,000 barrels. It therefore appears that 9 per cent of the total crop and one-fourth of the commercial crop was placed in cold storage.

Figure 1 shows the relative monthly holdings in cold storage compared with the peak load of December 1. It also shows graphically each month's holdings divided into barreled and boxed apple stock. The increase in the holdings of boxed apples during December made the decrease in the total stock very small, only 2.2 per cent being distributed during that month. The decreases during January, February, and March were about normal but during the month of April 21.7 per cent of the total season's holdings were disposed of as compared with the average of 14.6 per cent during this month in the three preceding seasons.

Table 2 shows the percentage of the December 1 holdings in storage on the first of each month in each section.

Table 2.—Monthly percentages of holdings of apples in cold storage during 1917-1918 season.

[Based upon December 1 holdings.]

Section.	Oct. 15	Nov. 1	Nov. 15	Dec. 1	Dec. 15	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1
New England	5.9	33.5	67.9	100.0	105.5	108.1	84.5	53.2	45.6	15.7	2.7
Middle Atlantic	29.6	61.9	82.9	100.0	104.2	108.4	83.6	56.2	37.5	15.1	3.9
South Atlantic	59.2	91.9	101.6	100.0	71.5	84.5	67.6	43.5	26.8	9.1	1.0
North Central (E)	31.7	65.4	88.7	100.0	104.1	104.3	90.6	65.0	45.2	21.2	7.1
North Central (W)	38.8	77.5	94.7	100.0	101.1	96.9	83.0	55.3	34.4	12.8	2.2
South Central	30.3	71.2	97.3	100.0	94.2	88.8	83.0	53.8	29.8	12.7	2.0
Western (N)	41.0	64.6	93.8	100.0	81.2	76.6	72.5	56.9	26.8	5.8	0.9
Western (S)	47.7	80.2	100.6	100.0	89.5	113.2	93.3	66.9	45.6	21.7	3.7
United States	37.	70.5	91.4	100.0	93.9	97.8	82.2	56.7	36.3	14.6	3.4

Table 3 shows the same data for the barreled apples and table 4 shows the percentage of the January 1 boxed apple holdings in storage monthly.

Table 3.—Monthly percentages of holdings of barreled apples in cold storage during 1917-1918 season.

[Based upon December 1 holdings.]

Section.	Oct. 15	Nov. 1	Nov. 15	Dec. 1	Dec. 15	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1
New England	4.2	26.4	67.2	100.0	104.5	103.4	81.2	53.3	40.7	14.0	2.5
Middle Atlantic	34.6	71.4	91.7	100.0	92.8	86.2	63.0	42.1	25.8	9.5	3.2
South Atlantic	61.2	94.1	102.9	100.0	69.8	82.9	66.2	42.8	25.7	8.0	0.7
North Central (E)	37.1	73.9	92.9	100.0	98.4	93.1	80.1	57.7	41.1	19.9	7.4
North Central (W)	49.6	90.8	103.1	100.0	93.6	85.4	73.2	48.6	28.0	9.9	1.4
South Central	37.9	86.5	104.2	100.0	84.9	71.9	56.9	33.1	15.5	4.4	0.5
Western (N)	0	0	0	0	0	0	0	0	0	0	.0
Western (S)	0	0	0	0	0	0	0	0	0	0	.0
United States	41.3	78.3	95.7	100.0	88.4	86.9	70.0	47.2	30.0	11.9	3.3

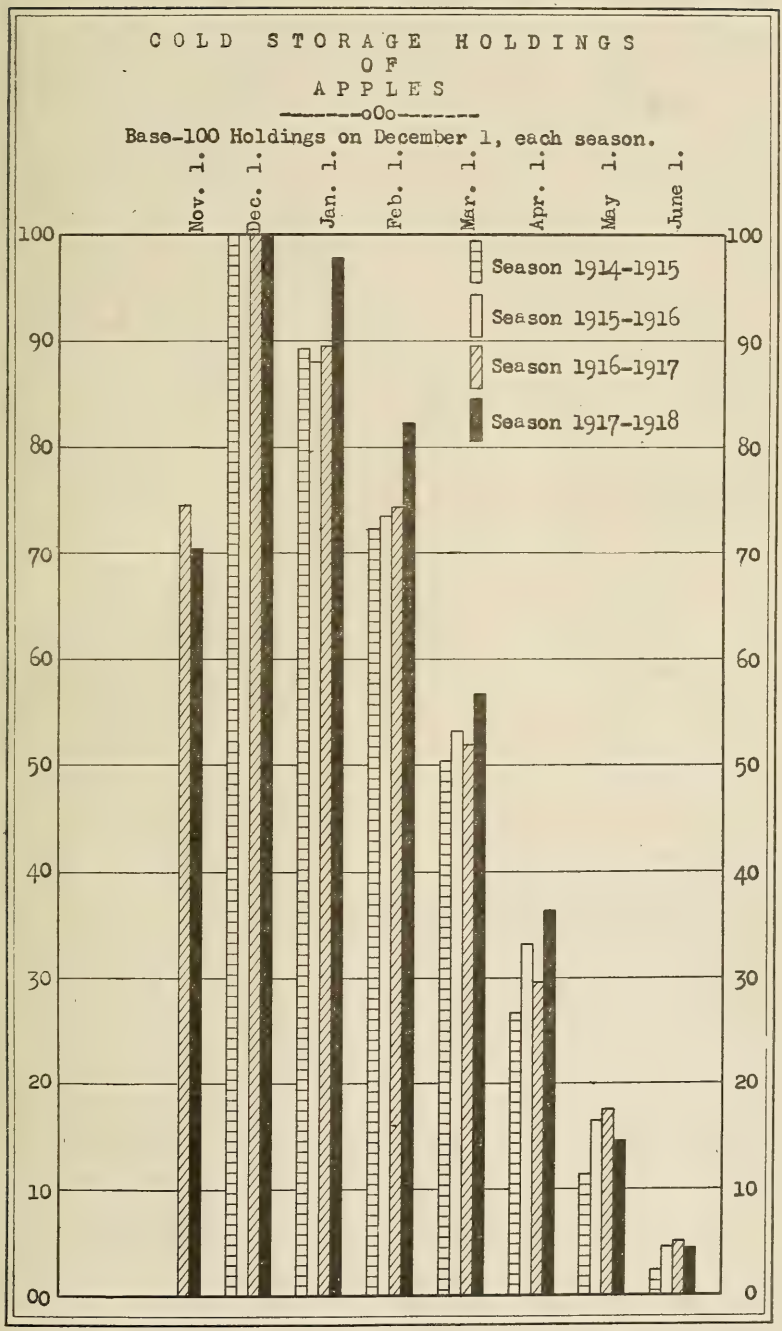
COLD STORAGE HOLDINGS
OF
APPLES
Base-100 Holdings on December 1, each season.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
Apr. 1.
May 1.
June 1.
Season 1914-1915
Season 1915-1916
Season 1916-1917
Season 1917-1918
100
90
80
70
60
50
40
30
20
10
0

Fig. 2.

Table 4.—Monthly percentages of holdings of boxed apples in cold storage during 1917-1918 season.

[Based upon January 1 holdings.]

Section.	Oct. 15	Nov. 1	Nov. 15	Dec. 1	Dec. 15	Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	June 1
New England	1.4	21.8	48.9	62.0	82.5	100.0	85.3	53.2	50.2	32.3	2.9
Middle Atlantic	4.1	6.2	19.8	47.6	76.8	100.0	95.7	64.5	44.8	19.6	3.4
South Atlantic	16.2	39.3	63.0	85.3	97.5	100.0	82.0	49.4	41.6	26.2	5.3
North Central (E)	3.5	18.0	44.7	66.6	85.3	100.0	89.9	63.5	41.1	17.8	3.7
North Central (W)	11.1	36.3	62.3	81.1	97.7	100.0	85.4	61.0	40.0	16.0	3.1
South Central	12.0	31.6	63.2	75.1	81.3	100.0	99.3	69.5	42.5	21.0	3.6
Western (N)	53.5	84.3	122.4	130.5	106.0	100.0	94.6	74.3	35.0	7.6	1.3
Western (S)	40.2	69.6	87.1	88.2	81.2	100.0	82.7	59.5	40.4	19.2	3.4
United States	24.2	42.6	66.1	82.9	88.1	100.0	88.9	64.5	40.4	16.6	3.0

Figure 2 shows the percentage of the December 1 apple holdings reported monthly to the Bureau of Markets for four seasons. The maximum holdings of each season occurring on December 1 are taken as a basis for each season's percentages. Table 5 shows the actual holdings reported on December 1 each season in barrels and boxes and the percentage of increase or decrease in holdings over the previous season. It also shows the percentage of the stock that was packed in boxes.

Table 5.—December 1 holdings of apples in cold storage.

Year.	Storages reporting.	Barrels.	Boxes.	Percentage packed in boxes.	Combined holdings expressed in barrels.	Increase or decrease over previous season.
				Per cent.		Per cent.
1914	340	3,347,050	4,143,306	29.2	4,728,152	
1915	367	4,213,203	3,684,557	22.6	5,441,389	+13.5
1916	520	3,166,301	3,977,227	29.5	4,492,043	—32.6
1917	552	3,306,037	4,574,076	31.6	4,830,729	— 1.4

Tables 6 to 8, inclusive, show the movement of apples to and from storage for the four seasons for which the Bureau of Markets has compiled data. In these tables the figures represent the percentages of the December 1 holdings which were placed in or removed from storage during the different months. The only exception to this rule is in the percentages showing the movement of boxed apples from storage during the season of 1917-1918. These are based on the holdings of January 1, as the peak load of boxed apple holdings for this season occurred on that date.

Table 6.—Monthly percentages of increases and decreases in cold storage holdings of apples.

Season.	Per cent of increase.				Per cent. of decrease.						Balance on hand June 1.
	Before Oct. 15	Oct. 16-30	Nov. 1-15	Nov. 16-30	Dec.	Jan.	Feb.	Mar.	Apr.	May	
1914–1915	.....	.....	.....	.....	10.7	17.1	21.9	24.1	14.8	9.1	2.3
1915–1916	.....	.....	.....	.....	12.0	14.7	20.1	20.0	16.7	11.9	4.6
1916–1917	38.1	36.4	20.0	5.5	10.4	15.3	22.4	22.2	12.2	12.4	5.1
1917–1918	36.3	34.0	21.3	8.4	2.2	15.6	25.5	20.4	21.7	11.2	3.4

Table 7.—Monthly percentages of increases and decreases in cold storage holdings of barreled apples.

Season.	Per cent. of increase.				Per cent. of decrease.						Balance on hand June 1.
	Before Oct. 15	Oct. 16-30	Nov. 1-15	Nov. 16-30	Dec.	Jan.	Feb.	Mar.	Apr.	May	
1914–1915	.....	.....	.....	.....	12.1	19.2	21.1	23.5	14.5	8.4	1.2
1915–1916	.....	.....	.....	.....	12.2	14.2	19.9	20.4	17.3	12.2	3.8
1916–1917	42.2	40.7	15.9	1.2	15.1	18.6	18.6	19.4	12.0	11.3	5.0
1917–1918	41.3	36.8	17.8	4.1	13.1	16.9	22.8	17.2	18.1	8.6	3.3

Table 8.—Monthly percentages of increases and decreases in cold storage holdings of boxed apples.

Season.	Per cent. of increase.				Per cent. of decrease.						Balance on hand June 1.
	Before Oct. 15	Oct. 16-30	Nov. 1-15	Nov. 16-30	Dec.	Jan.	Feb.	Mar.	Apr.	May	
1914–1915	.....	.....	.....	.....	6.7	11.3	24.3	25.7	15.6	11.0	5.4
1915–1916	.....	.....	.....	.....	11.5	16.5	20.9	18.1	14.6	11.5	6.9
1916–1917	29.1	25.7	29.6	15.6	0.1	8.3	30.9	28.1	12.3	15.1	5.2
1917–1918	24.2	18.4	23.5	22.0	+11.9	11.1	24.4	24.1	23.8	13.6	3.0

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF CREAMERY BUTTER.

On May 1, 1917, the beginning of the 1917-1918 season, the total holdings of creamery butter as reported by 304 cold storage plants amounted to 2,695,473 pounds. This was about one and one-fourth more than was held at the beginning of the previous season. The movement into storage was much slower, however, than in the preceding season as by June 1 there was only one-fifth more and by July 1 there was 17.1 per cent less than on the same dates the previous year. The August 1 holdings were 20.5 per cent less than in 1916-1917 but by September 1 the difference was only 10.6 per cent and on the first of October they were only 3 per cent less. There was an increase of 76,952 pounds during the month of September as compared with a decrease of 8,192,630 pounds during September of the previous season.

The holdings in the Western North section reached their highest point in August and in the Western South in September. The holdings in the North Central West section were the largest in September, while in the Middle Atlantic States the maximum holdings occurred on November 1. The monthly decrease was most rapid in the North Central West and Western South sections, while the decreases in the New England, South Atlantic and South Central sections were the slowest. These increases and decreases probably occurred earlier in the producing sections and later in the consuming sections on account of the shipments from western to eastern storages.

The largest quantity reported to the Bureau of Markets at any one time during the season was 106,475,760 pounds, representing the holdings of 404 storages on October 1. An estimate of the holdings of the storages not reporting for October

1, based upon their holdings for other months, would increase this amount to approximately 108,750,000 pounds.

Table 9 shows the total holdings of that date segregated by sections and a comparison of the holdings of 332 storages with the amounts they held on the same date of the previous season.

Table 9.—Cold storage holdings of creamery butter as reported on October 1, 1917.

Section.	Reported for October 1, 1917.			Comparison with October 1, 1916.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	October 1, 1916.	October 1, 1917.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	31	24,670,458	23.2	27	25,044,351	22,802,188	— 9.0
Middle Atlantic	97	32,362,904	30.3	82	30,883,321	30,777,908	— 0.3
South Atlantic	36	2,094,113	2.0	24	1,475,272	1,630,806	+10.5
North Central (E)	70	28,824,677	27.1	54	27,359,933	24,233,900	—11.4
North Central (W)	61	11.899,834	11.2	56	8,915,165	11,571,681	+29.7
South Central	41	1,584,998	1.5	36	1,268,628	1,576,298	+24.3
Western (N)	33	1,807,300	1.7	26	1,930,854	1,649,556	—14.6
Western (S)	35	3,231,476	3.0	27	3,644,049	3,214,539	—11.8
Total	404	106,475,760	100.0	332	100,521,573	97,456,876	— 3.0

This comparison, however, does not show the comparative amounts stored in the two seasons. The peak load of the 1916-1917 season occurred on September 1, while in the 1917-1918 season the largest quantity was held on October 1. If we compare the holdings of the 275 storages reporting for these two dates they show 106,113,839 pounds on September 1, 1916, and 94,712,624 pounds on October 1, 1917, a decrease of 11,401,215 pounds or 10.7 per cent.

Figure 3 shows graphically the holdings of each month compared with those of October 1 for the seasons of 1916-1917, 1917-1918 and a ten-year average of the reports of the Associated Warehouses. It will be observed both there and in table 10, which shows the monthly increases and decreases, that the greatest increases were made during June and July, 72,538,825 pounds or approximately 78 per cent of the total holdings being stored during these months.

Table 10.—Monthly and semi-monthly cold storage holdings of creamery butter as compared with previous reports.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current report.	Preceding report.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
June 1	235	8,436,079	2,698,017	+ 5,738,062	+212.7
June 15	254	22,581,838	8,507,640	+14,074,198	+165.4
July 1	271	46,631,533	23,224,309	+23,407,224	+100.8
July 15	241	64,525,601	47,497,334	+17,028,267	+ 35.9
August 1	261	84,101,347	66,072,211	+18,029,136	+ 27.3
September 1	294	98,683,757	86,235,920	+12,447,837	+ 14.4
October 1	320	98,749,922	98,672,970	+ 76,952	+ 0.1
November 1	357	98,886,972	105,253,730	— 6,366,758	— 6.0
December 1	354	77,219,724	97,211,996	—19,992,272	— 20.6
January 1	337	46,956,949	74,711,024	—27,754,075	— 37.1
February 1	343	22,249,328	43,191,036	—20,941,708	— 48.5
March1	357	18,034,428	26,160,246	— 8,125,818	— 31.1
April 1	360	14,581,614	19,075,492	— 4,493,878	— 23.6

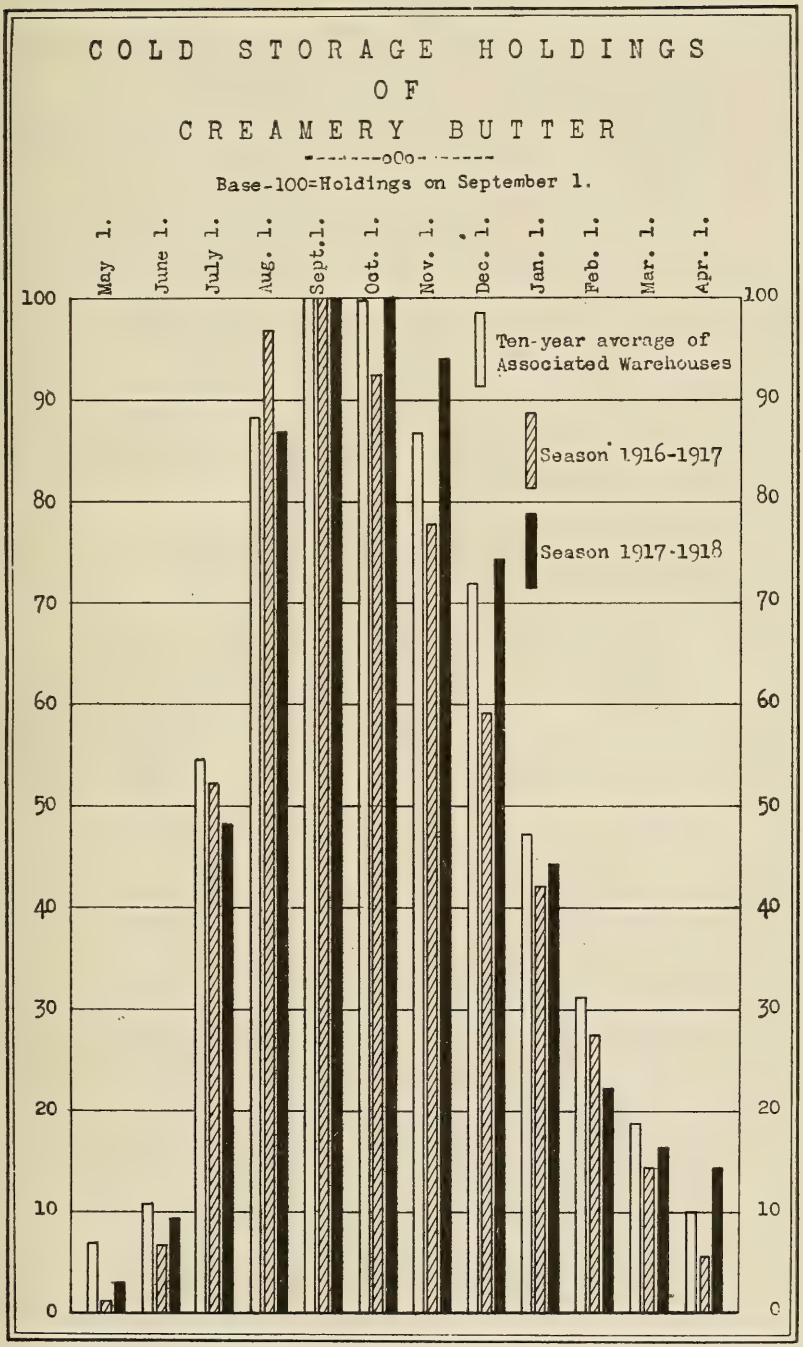
COLD STORAGE HOLDINGS
OF
CREAMERY BUTTER
Base-100=Holdings on September 1.
May 1.
June 1.
July 1.
Aug. 1.
Sept. 1.
Oct. 1.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
Apr. 1.
100
90
80
70
60
50
40
30
20
10
0
Ten-year average of Associated Warehouses
Season 1916-1917
Season 1917-1918

Fig. 3.

Table 11 shows the percentages of monthly increases and decreases for this and the past season compared with a ten-year average compiled from the reports of the Associated Warehouses from 1907 to 1916, inclusive.

Table 11.—Monthly percentages of increases and decreases in holdings of cold storage creamery butter.

Date.	Per cent. of increase.					Per cent. of decrease.						
	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Assoc. Whse.[1]	6.9	3.7	43.8	33.8	11.8	0.2	13.0	15.0	24.6	16.1	12.4	8.7
1916-1917	1.1	5.6	45.4	44.7	3.2	7.8	14.5	18.6	17.2	14.4	13.2	8.7
1917-1918	3.0	6.3	38.8	38.8	13.0	+0.1	6.1	19.7	30.1	22.0	6.8	2.0

[1] Reports of Associated Warehouses, 1907 to 1916, inclusive.

In this connection it is interesting to note the comparative exports of butter during these two seasons as shown in table 12. These data were compiled from the reports of the U. S. Department of Commerce.

Table 12.—Monthly exports of butter during the distribution of the cold storage stocks of creamery butter for the seasons of 1916-1917 and 1917-1918.

Month.	1916-1917.	1917-1918.
	Pounds.	Pounds.
October	8,065,203	275,017
November	4,580,020	262,800
December	2,298,548	1,348,740
January	1,888,825	4,195,551
February	296,062	821,421
March	487,386	4,309,478
April	371,519	3,636,006
Total	17,987,563	14,849,013

On June 1 there were 9,010,869 pounds in cold storage and during the months of June and July the increases represented 77.6 per cent. of the total holdings or 77,471,798 pounds. The Producers' Price-Current showed a range of prices for "creamery firsts" of from 36 to 41.5 cents per pound on the New York market during June and July, the average during the period being 38.16 cents per pound. From October 1, 1917, to March 1, 1918, the total holdings were reduced by 84.7 per cent or 87,667,457 pounds. The selling price of "creamery held firsts" on the New York market during this period ranged from 49.75 to 47 cents, the average being 44.02 cents per pound.

Table 13.—Daily prices of cold storage butter on New York market during season 1917-1918.

Compiled from The Producers' Price-Current.

[June and July prices for "creamery firsts;" other prices for "creamery held firsts."]

Date.	June, 1917.		July, 1917.		Oct., 1917.		Nov., 1917.		Dec., 1917.		Jan., 1918.		Feb., 1918.		Date.
	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	
	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	Cents	
1	40.5	41.5	[1]	[1]	44.	44.5	42.	43.25	41.5	42.5	[2]	[2]	46.5	47.	1
2	40.	41.	36.25	37.25	44.	44.5	41.75	42.75	[1]	[1]	44.5	46.	46.5	47.	2
3	[1]	[1]	36.75	37.75	44.	44.5	41.75	42.75	41.5	43.	45.5	46.	[1]	[1]	3
4	39.5	40.5	[2]	[2]	44.	44.5	[1]	[1]	42.	43.5	45.5	46.	46.75	47.	4
5	39.5	40.5	37.25	38.25	44.	44.5	41.75	42.5	42.	43.5	45.5	46.	46.75	47.	5
6	39.	40.5	37.75	38.75	43.5	44.	[3]	[3]	42.	43.5	[1]	[1]	47.	47.	6
7	39.5	41.	37.75	38.75	[1]	[1]	41.75	42.5	42.	43.5	45.5	46.	47.	47.	7
8	39.	40.	[1]	[1]	43.	43.75	41.5	42.25	42.	43.5	45.5	46.	47.	47.	8
9	38.5	39.5	38.	39.	43.	43.75	41.	42.	[1]	[1]	45.5	46.	47.	47.	9
10	[1]	[1]	38.5	39.25	43.	44.	[3]	[3]	42.	44.	45.5	46.	[1]	[1]	10
11	38.25	39.	38.5	39.25	43.25	44.	[1]	[1]	42.5	45.	45.5	46.	47.	47.	11
12	37.5	38.25	38.25	39.25	[3]	[3]	[3]	[3]	43.	45.	45.5	46.	[3]	[3]	12
13	37.5	38.25	38.	38.75	43.25	44.25	40.75	41.75	42.5	45.	[1]	[1]	44.	47.	13
14	36.25	36.75	38.	38.75	[1]	[1]	40.75	41.75	42.5	45.	45.5	46.	44.	47.	14
15	36.25	36.75	[1]	[1]	43.	43.75	[3]	[3]	42.5	45.	46.	46.5	44.	47.	15
16	36.5	37.25	37.75	38.5	42.5	43.5	40.75	42.	[1]	[1]	46.	46.5	44.	47.	16
17	[1]	[1]	37.5	38.25	42.	43.	40.75	42.	42.5	45.	46.	46.5	[1]	[1]	17
18	36.75	37.5	37.5	38.25	42.	43.	[1]	[1]	42.5	45.	46.	46.5	44.	47.	18
19	36.75	37.5	37.5	38.5	41.5	42.5	40.75	42.	42.5	45.	46.5	47.	44.	47.	19
20	37.	37.75	37.5	38.75	41.5	42.5	40.75	42.	42.5	45.	[1]	[1]	44.	47.	20
21	[3]	[3]	37.75	39.	[1]	[1]	40.75	42.	43.	45.	46.5	47.	44.	47.	21
22	37.5	38.25	[1]	[1]	42.	43.	41.	42.	43.	45.	46.5	47.	[2]	[2]	22
23	38.	39.	38.5	39.5	42.5	43.25	41.	42.	[1]	[1]	46.5	47.	44.	47.	23
24	[1]	[1]	38.25	39.25	[3]	[3]	41.	42.	43.	45.	46.5	47.	[1]	[1]	24
25	37.75	38.75	38.25	39.25	43.	43.75	[1]	[1]	[2]	[2]	46.5	47.	44.	47.	25
26	37.5	38.5	37.75	38.75	43.	43.75	41.	42.	43.	45.	46.5	47.	44.	47.	26
27	37.	38.	38.	38.75	43.	43.75	41.5	42.5	43.	45.	[1]	[1]	44.	47.	27
28	36.75	37.5	38.	38.75	[1]	[1]	41.5	42.5	43.25	45.25	46.5	47.	44.	47.	28
29	36.	37.	[1]	[1]	42.5	43.5	[3]	[3]	44.	45.75	46.5	47.	[3]	[3]	29
30	36.	37.	38.5	39.25	42.5	43.5	41.5	42.5	[1]	[1]	46.5	47.	[3]	[3]	30
31	.....	.....	38.5	39.25	42.25	43.25	.....	.....	44.5	46.	46.5	47.	[3]	[3]	31
Av.	38.26		38.31		43.25		41.72		43.58		46.25		46.08		Av.

[1] Sunday. [2] Holiday. [3] No quotations.

Table 14.—Cost of "creamery firsts" butter placed in cold storage during June and July, 1917, if bought at New York market prices.

Date.	Percentage of total holdings.	Total moved into storage.	Price per pound.	Cost.
	Per cent.	Pounds.	Cents.	Dollars.
June 1-15	14.8	15,758,412	39.07	6,156,812
June 16-30	24.0	25,554,182	37.40	9,557,264
July 1-15	20.1	21,401,628	38.18	8,171,142
July 16-30	18.7	19,910.967	38.40	7,645,811
Total	77.6	82,625,189	38.16	$31,531,029

The months of June and July being the time of accumulation and the period from October 1 to March 1 the time of distribution, it may be assumed that in general the stock that went into storage in the former months at 38.16 cents was sold in the latter months at 44.02 cents, a gross profit of 5.86 cents per pound or 15.35 per cent on the investment. From this apparent profit, deduction should be made of approximately eight-tenths of a cent per pound to cover storage and insurance charges, making the actual profit slightly more than five cents per pound, from which must be deducted interest on the money invested to ascertain the net profit.

Table 15.—Selling price of "creamery firsts" butter delivered from cold storage during season of 1917-1918 at New York market prices.

Date.	Percentage of total holdings.	Moved out of storage.	Price per pound.	Selling price.
	Per cent.	Pounds.	Cents.	Dollars.
October	6.1	6,495,021	43.25	2,809,097
November	19.7	20,975,725	41.72	8,751,072
December	30.1	32,049,204	43.58	13,967,043
January	22.0	23,424,667	46.25	10,833,908
February	6.8	7,240,352	46.08	3,336,354
Total	84.7	90,184,969	44.02	$39,697,474

In the season of 1916-1917 the range of prices for "creamery firsts" during June and July was from 27 to 30 cents, the average price being 28.05 cents per pound. The prices of "creamery held firsts" for the months of October to February, inclusive, ranged from 33.75 to 38.5 cents, the average being 36.04 cents per pound. The operation, therefore, showed an apparent profit of 7.79 cents per pound, from which must be deducted the costs of storage and interest on investment to arrive at the net profit.

The reports of the Bureau of Markets do not show the movement into storage during the season of 1915-1916. The price quotations, however, for "creamery firsts" during the months of June and July ranged from 24 to 28 cents, the average of the daily quotations being 26.64 cents per pound. From November 1, 1915, to March 1, 1916, the prices of "creamery held firsts" ranged from 26 to 28.5 cents, the average being 27.45 cents per pound. There was therefore an apparent profit of 0.81 cents per pound, an amount barely sufficient to cover

the costs of storage, leaving little or no balance to pay interest on the investment or to provide for any profit on the transaction.

Figure 4 shows the weekly average prices of creamery butter on the New York market during some of the months of accumulation and distribution for the past three seasons. The prices are obtained from the quotations in The Producers' Price-Current.

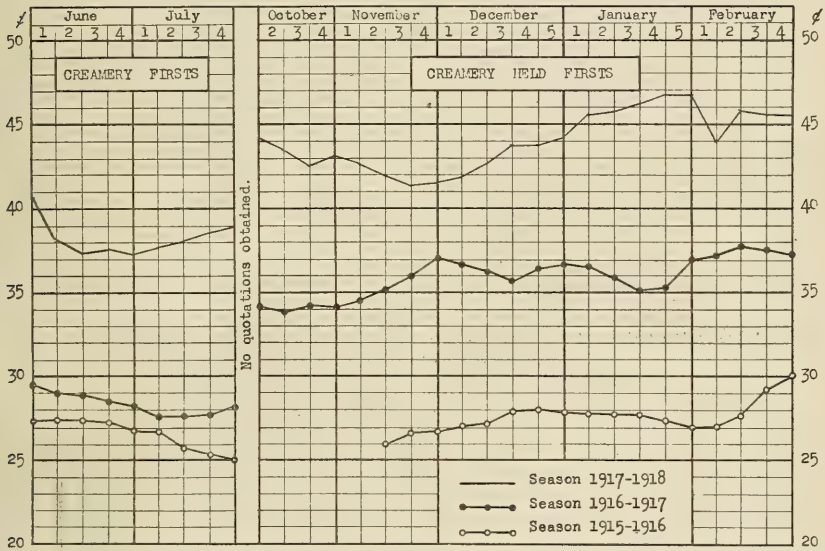

Fig. 4.—Weekly average prices of cold storage creamery butter on the New York market. Compiled from the Producers' Price-Current. (Weeks are numbered from 1 to 5.)

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF PACKING STOCK BUTTER.

The term "packing stock butter" used in the reports of the Bureau of Markets is intended to include all dairy and farm made butter which is to be used as bakers' stocks or for making renovated or process butter.

The first month's report issued on September 1, 1917, showed the holdings of 89 cold storage warehouses to be 2,531,215 pounds. This was approximately 60 per cent more than was stored on the same date the previous season. As many cold storage warehouses did not report for the month of September this did not include all holdings. The comparisons of this month's holdings with later and more complete monthly reports would seem to indicate that there were approximately three and one-half million pounds stored on September 1, 1917.

Table 16 shows the holdings as reported on September 1, 1917, segregated by sections of the country and a comparison of the holdings of 55 storages with the amount held on September 1, 1916, and table 17 shows the holdings of each month compared with those of the preceding month.

Table 16.—Cold storage holdings of packing stock butter as reported on September 1, 1917.

Section.	Reported for September 1, 1917.			Comparison with October 1, 1916.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	September 1, 1916.	September 1, 1917.	Decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	0	0	0	0	0	0	0
Middle Atlantic	6	135,769	5.4	2	243,800	83,400	65.8
South Atlantic	6	238,762	9.4	4	291,774	190,080	34.9
North Central (E)	25	749,562	29.6	16	1,455,536	516,936	64.5
North Central (W)	35	1,261,952	49.9	24	1,501,756	607,522	59.5
South Central	9	56,713	2.2	5	71,890	29,298	59.2
Western (N)	5	26,914	1.1	1	48,313	6,249	87.1
Western (S)	3	61,543	2.4	3	82,005	61,543	25.0
Total	89	2,531,215	100.0	55	3,695,074	1,495,028	59.5

Table 17.—Monthly cold storage holdings of packing stock butter compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
October 1	72	1,622,720	2,295,808	673,088	29.3
November 1	98	1,473,851	2,373,940	900,089	37.9
December 1	108	1,661,496	1,751,900	90,404	5.2
January 1	110	1,443,466	1,865,618	422,152	22.6
February 1	114	1,358,179	1,578,784	220,605	14.0
March 1	130	857,831	1,535,997	678,166	44.2

No reports were received showing the movement of packing stock butter into storage. The holdings decreased during the months of September and October but increased during November. Decreases were again shown in December, January and February, and on March 1 the holdings amounted to 22.2 per cent of the amount stored on September 1. Figure 5 shows graphically comparative monthly holdings from September to March, inclusive.

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF AMERICAN CHEESE.

The reports of the Bureau of Markets show that an exceptionally large quantity of American cheese was placed in cold storage during the 1917-1918 season. The reports from 464 cold storage plants showed holdings of 92,449,996 pounds on October 1, 1917. As all the cold storage warehouses did not report their holdings on that date, this amount did not include all the stock. A careful estimate based on the holdings of other months by the remaining storages shows that the total

amount on hand on October 1, 1917, was approximately 95,000,000 pounds. On this date 31 per cent of the total stock was stored in New York State and 12.4 per cent in New York city. Wisconsin storages held 12.7 per cent while only 1.6 per cent was stored in Minnesota. The largest quantity stored in any one city was held in Chicago, the holdings there amount to 19.8 per cent. Boston storages held 6.5 per cent, San Francisco storages 2.9 per cent and less than 1 per cent was held in Philadelphia.

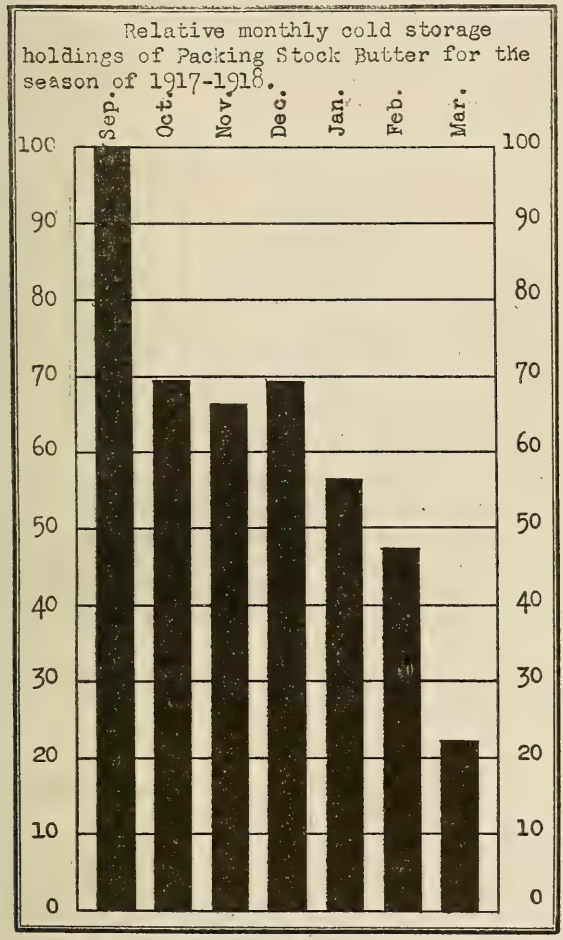

Fig. 5.

Table 18 shows the holdings of October 1, 1917, segregated by sections and also a comparison of the holdings of 301 storages on that date with the amount they held on September 1 of the previous year.

This comparison shows an increase of 52.4 per cent. The holdings of October 1, 1917, are compared with those of September 1, 1916, as the storing season continued for a longer period in 1917 and the largest quantities reported during these seasons were held on those dates. The holdings of the 1916-1917 and 1915-1916 seasons were approximately the same, there being a difference of less than one per cent.

At the beginning of the season on May 1, 1917, there were almost 8,000,000 pounds already in storage. This quantity was no doubt partly a carry-over from the previous season and partly new stock going into storage very early. These holdings were increased by more than 2,000,000 pounds during the month of May. The bulk of the holdings, however, was placed in cold storage during the months of June, July and August, 87.3 per cent of the total increases occurring in these months.

The largest quantity was stored during July, the reports of 307 storages showing an increase of 28,915,736 pounds during that month. As all the storages did not report for both June 1 and July 1, this does not show the entire increase, and it is believed that the total movement into storage was approximately 32,000,000 pounds.

Table 18.—Cold storage holdings of American cheese as reported October 1, 1917.

Section.	Reported for October 1, 1917.			Comparison with October 1, 1916.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	September 1, 1, 1916.	October 1, 1917.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	27	7,189,137	7.8	14	5,368,958	6,826,779	+ 27.2
Middle Atlantic	112	33,299,963	36.0	70	19,570,564	28,289,141	+ 44.5
South Atlantic	45	3,349.778	3.6	25	2,133,294	1,829,511	— 14.2
North Central (E)	101	35,046,307	37.9	70	12,920,190	26,031,363	+101.5
North Central (W)	60	3,807,940	4.1	44	3,134,781	3,581,400	+ 14.2
South Central	53	2,400,108	2.6	30	530,681	712,338	+ 34.2
Western (N)	30	1,165,397	1.3	21	1,023,029	914,722	— 10.6
Western (S)	36	6,191,366	6.7	27	4,087,351	6,154,639	+ 50.6
Total	464	92,449,996	100.0	301	48,768,848	74,339,893	+ 52.4

Table 19 shows the increases and decreases in holdings each month as compiled from the reports issued monthly by the Bureau. Figure 6 shows the relative quantities on hand on the first of each month during the past two seasons, and Table 20 shows the monthly percentage of increase and decrease for the two seasons for which the Bureau has compiled data.

Table 19.—Monthly cold storage holdings of American cheese as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
June 1	313	9,553,845	7,480,495	+ 2,073,350	+ 27.7
July 1	292	25,884,240	8,594,581	+17,289,659	+201.2
August 1	307	60,091,534	31,175,798	+28,915,736	+ 92.8
September 1	323	74,300,651	58,218,536	+16,082,115	+ 27.6
October 1	360	81,638,837	81,280,743	+ 358,094	+ 0.4
November 1	411	84,380,977	90,254,258	— 5,873,281	— 6.5
December 1	419	78,765,033	84,245,843	— 5,480,810	— 6.5
January 1	410	68,791,566	77,398,312	— 8,606,746	— 11.1
February 1	432	55,837,977	67,011,022	—11,173,045	— 16.7
March 1	448	47,726,437	60,204,975	—12,478,538	— 20.7
April 1	459	38,167,559	48,073,044	— 9,905,485	— 20.6
May 1	455	24,218,143	38,249,521	—14,031,378	— 36.7

Table 20.—Monthly percentages of increases and decreases in holdings of American cheese in cold storage.

Season.	Per ct. on hd. May 1	Per cent of increase.				Per cent of decrease.								Per ct. on hd. May 1.
		May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	
1916–1917	17.1	2.9	27.2	40.5	12.3	5.3	7.2	8.5	11.1	23.0	15.9	10.5	3.1	15.4
1917–1918	9.6	2.6	26.3	37.9	23 1	+0.5	6.5	7.0	9.4	14 9	12.0	9.6	14.7	25.9

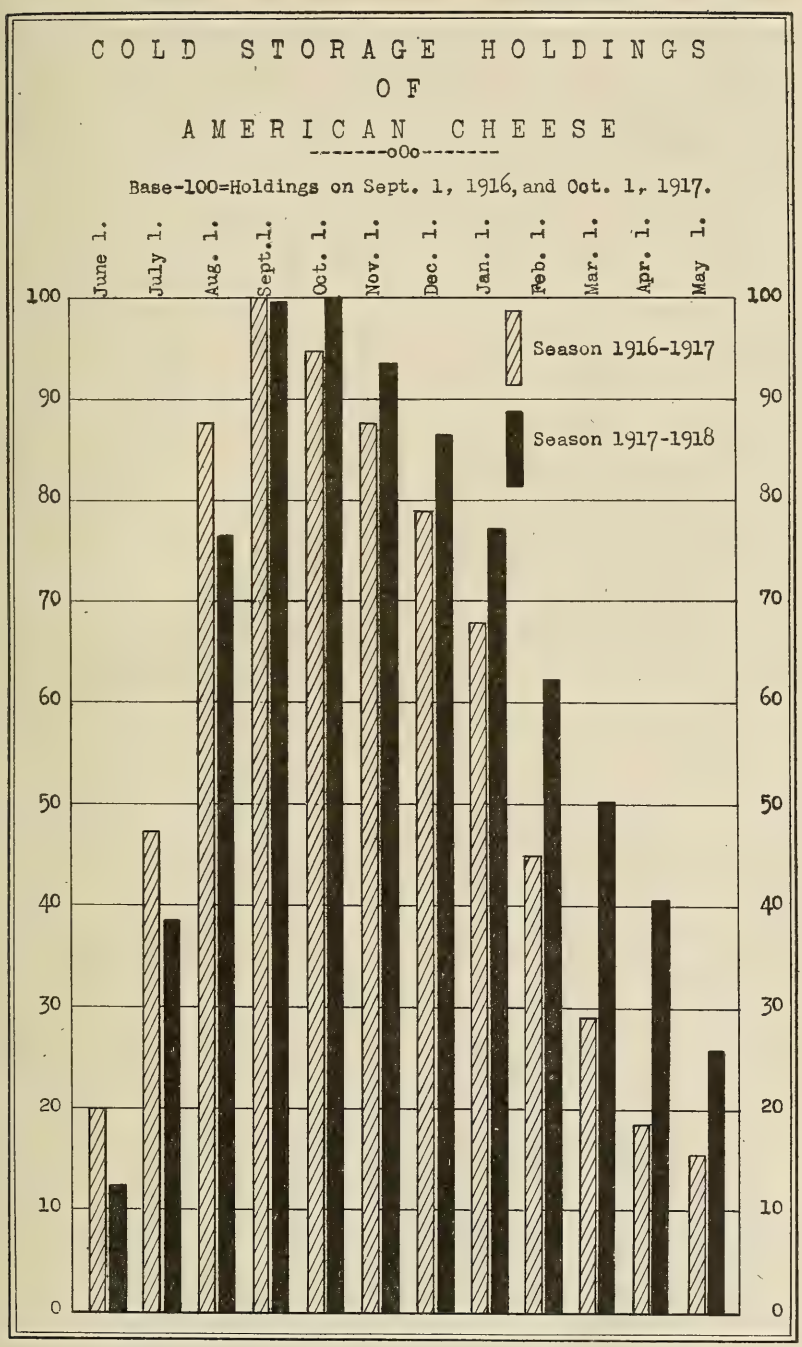
COLD STORAGE HOLDINGS
OF
AMERICAN CHEESE
--------oOo--------
Base-100=Holdings on Sept. 1, 1916, and Oct. 1, 1917.
June 1.
July 1.
Aug. 1.
Sept. 1.
Oct. 1.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
Apr. 1.
May 1.
Season 1916-1917
Season 1917-1918
100
90
80
70
60
50
40
30
20
10
0

Fig 6.

It will be observed both in the table and in the chart that the movement from cold storage was exceptionally slow. The decrease of 14.9 per cent in January, 1918, compared with the decrease of 23.0 per cent during January, 1917, is especially noticeable. In this connection a comparison of the exports of cheese for the two years as shown in Table 21 is very interesting.

Table 21.—Monthly exports of cheese as shown by the reports of the Department of Commerce.

Month.	1916-1917.	1917-1918.
	Pounds.	Pounds.
October	5,970,313	464,967
November	3,644,915	744,419
December	4,036,169	1,271,741
January	8,101,103	778,583
February	7,241,648	921,244
March	7,576,682	2,669,003
April	5,283,007	1,234,925
Total	41,853,837	8,084,882

The comparatively small quantity exported no doubt partly accounts for the slow movement from storage. On April 1 a quantity equal to 40.6 per cent of the holdings on October 1 was still in cold storage as compared with the 18.5 per cent of October 1, 1916, holdings held on April 1 of the previous season. The holdings decreased more than fourteen million pounds during April as compared with a decrease of about one and one-half million during April 1917. There still remained, however, a stock of 24,241,545 pounds on May 1.

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF CASE EGGS.

The largest number of case eggs reported in cold storage at any one time during the season was 6,602,711 cases as reported by 403 warehouses on August 1, 1917. This was 0.7 per cent more than was stored on the same date of the previous season. Table 23 shows the total holdings of that date segregated by sections and a comparison of the holdings with those of the previous year.

Table 23.—Cold storage holdings of case eggs as reported on August 1, 1917.

Section.	Reported for August 1, 1917.			Comparison with August 1, 1916.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	August 1, 1916.	August 1, 1917.	Increase or decrease.
	Number.	Cases.	Per cent.	Number.	Cases.	Cases.	Per cent.
New England	24	809,324	12.3	15	569,542	682,595	+ 19.8
Middle Atlantic	77	1,981,492	30.0	55	1,889,362	1,952,102	+ 3.3
South Atlantic	26	178,275	2.7	16	74,299	89,633	+ 20.6
North Central (E)	77	1,789,178	27.1	62	1,943,574	1,712,707	— 11.9
North Central (W)	76	1,168,990	17.7	70	1,082,026	1,094,876	+ 1.2
South Central	50	261,969	4.0	38	133,744	182,045	+ 36.1
Western (N)	34	92,899	1.4	22	79,262	71,855	— 9.3
Western (S)	39	320,584	4.8	34	288,320	316,439	+ 9.8
Total	403	6,602,711	100.0	312	6,060,129	6,102,252	+ 0.7

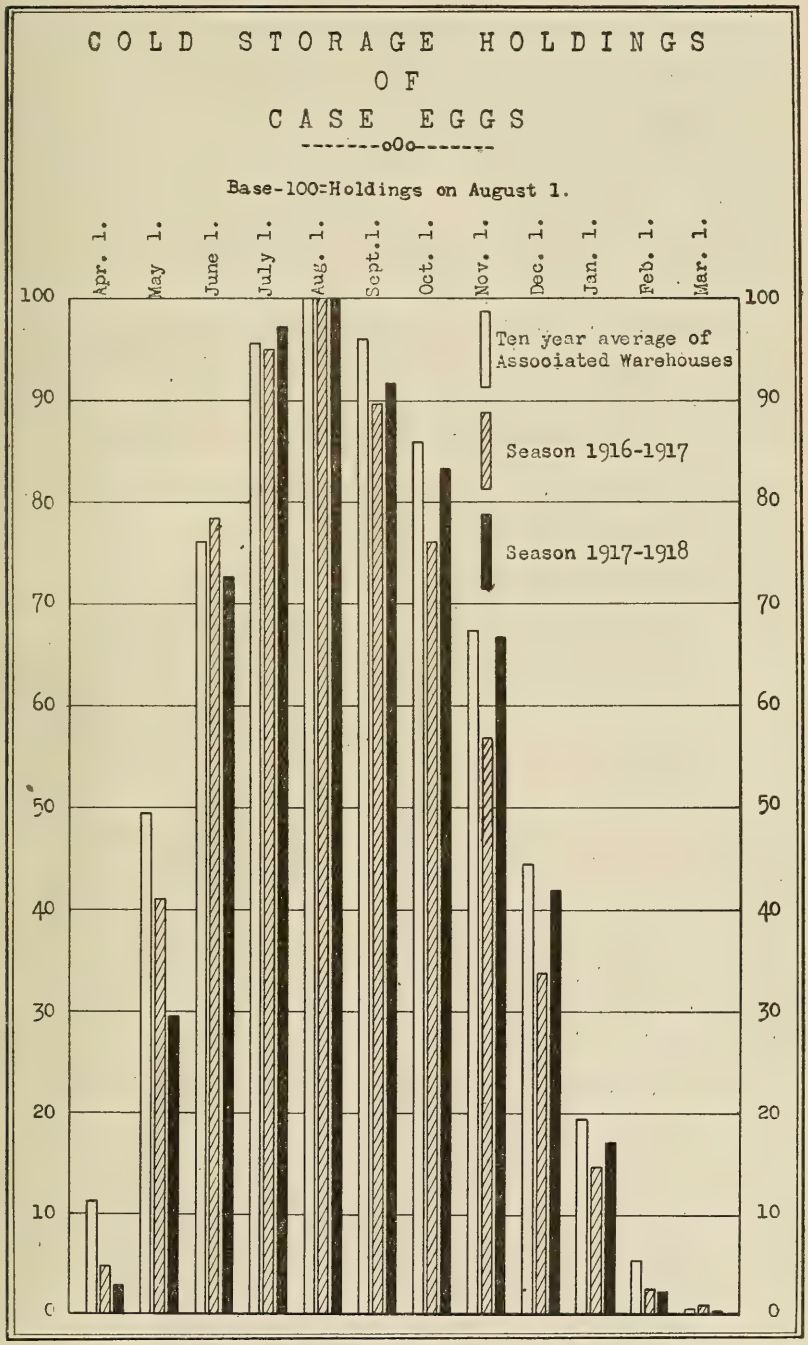
COLD STORAGE HOLDINGS
OF
CASE EGGS
Base-100=Holdings on August 1.
Apr. 1.
May 1.
June 1.
July 1.
Aug. 1.
Sept. 1.
Oct. 1.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
100
90
80
70
60
50
40
30
20
10
0
Ten year average of Associated Warehouses
Season 1916-1917
Season 1917-1918

Fig. 7.

More than 45 per cent of the total holdings on August 1, 1917, was stored in the cities of Chicago, New York, Boston and St. Louis. Chicago held the largest amount, 1,383,300 cases, amounting to 21 per cent of the total. New York came next with 1,060,266 cases, Boston third with 435,439 cases, and St. Louis fourth with 125,331 cases. The movement into storage began first in the Western states. Nearly one-fourth of the holdings in the Western South section were in storage by April 1. By May 1 more than half of the holdings in that section and 35 per cent in the Western North section were stored. The holdings in the latter section reached their highest point on July 1.

Table 24 shows the holdings as reported monthly compared with the holdings of the preceding month, and figure 7 shows graphically the holdings of each month compared with those of August 1 for the past two seasons and also for a ten-year average of the reports of the Associated Warehouses.

Table 24.—Monthly and semi-monthly cold storage holdings of case eggs as compared with previous report.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current report.	Preceding report.		
	Number.	Cases.	Cases.	Cases.	Per cent.
April 1	293	164,518	5,280	+ 159,238	+3,015.9
May 1	313	1,818,703	165,659	+ 1,653,044	+ 997.9
May 15	332	3,221,970	1,848,073	+ 1,373,897	+ 74.3
June 1	324	4,481,827	3,711,098	+ 770,729	+ 20.8
June 15	311	5,661,947	4,446,940	+ 1,215,007	+ 27.3
July 1	354	6,105,570	5,455,685	+ 649,885	+ 11.9
August 1	326	6,194,173	6,036,576	+ 157,597	+ 2.6
September 1	360	5,893,404	6,508,813	— 615,813	— 9.5
October 1	392	5,592,897	5,975,875	— 382,978	— 6.4
November 1	407	4,429,888	5,526,629	— 1,096,741	— 19.8
November 15	388	3,653,538	4,420,374	— 766,836	— 17.3
December 1	405	2,799,012	3,677,203	— 878,191	— 23.9
December 15	411	1,618,181	2,259,724	— 641,543	— 28.4
January 1	414	988,228	1,648,961	— 660,733	— 40.1
February 1	408	191,520	1,179,950	— 988,430	— 83.8

The comparative monthly movement to and from storage for the past two seasons is shown in Table 25 and also for an average of ten years as compiled from the reports of the Associated Warehouses for 1907 to 1916, inclusive.

Table 25.—Monthly percentages of increases and decreases in holdings of cold storage eggs.

Season.	Per cent. of increases.					Per cent. of decreases.						
	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Assoc. Whse.[1]	11.1	38.4	26.5	19.6	4.4	4.0	10.3	18.3	22.9	25.2	14.0	4.9
1916-1917	4.7	36.3	37.3	16.7	5.0	10.3	13.7	19.2	23.1	19.2	12.1	1.7
1917-1918	2.8	26.7	43.0	24.7	2.8	8.4	8.4	16.4	25.0	24.7	15.0	1.9

[1] Reports of Associated Warehouses, 1907 to 1916, inclusive.

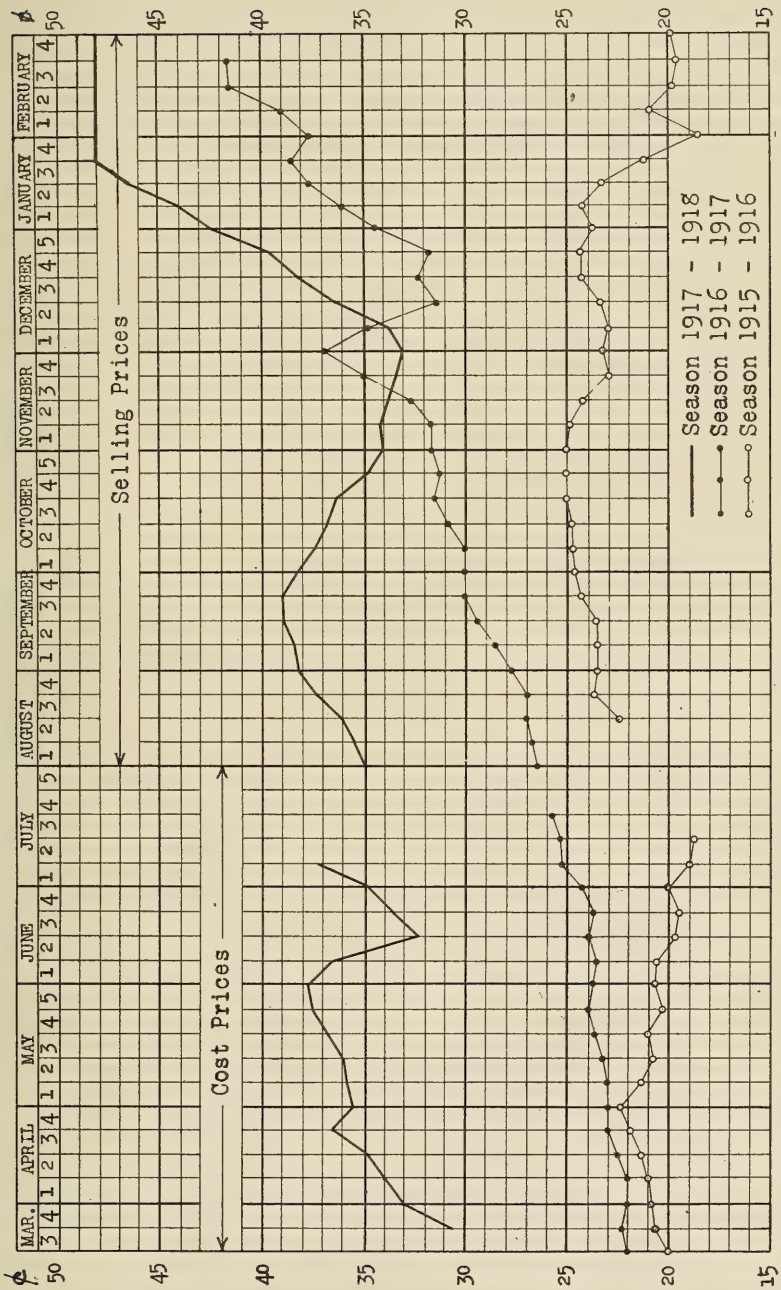

Fig. 8.—Weekly average prices of cold storage eggs on New York market. Compiled from the Producers' Price-Current. (Weeks are numbered from 1 to 5.)

The season, taken as a whole, represented an unprofitable investment on the part of the dealers in cold storage eggs. Table 26 shows the daily quotations of "storage packed firsts" on the New York market from March 26 to July 10, inclusive, as compiled from The Producers' Price-Current.

Table 26.—Prices of "storage packed firsts" case eggs on the New York market for season 1917-1918.

[Compiled from Producers' Price-Current.]

Date.	March.		April.		May.		June.		July.		Date.
	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	
	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	
1	.....	.....	[1]	[1]	35.	36.5	37.5	38.	[1]	[1]	1
2	.....	.....		34.	35.	36.	37.5	38.	35.5	36.	2
3	.....	.....	34.	34.5	35.5	36.	[1]	[1]	35.5	36.	3
4	.....	.....		34.5	35.5	36.	37.	38.	[2]	[2]	4
5	.....	.....	34.	34.5	36.	36.5	37.	38.	36.	36.5	5
6	.....	.....	34.	34.5	[1]	[1]	36.	37.	36.	36.5	6
7	.....	.....		34.	36.	37.	35.5	36.5	36.	36.5	7
8	.....	.....	[1]	[1]	36.	37.	34.5	35.	[1]	[1]	8
9	.....	.....		33.	35.	36.	34.	38.	36.	36.5	9
10	.....	.....	33.75	34.25	35.	36.	[1]	[1]	36.	36.5	10
11	.....	.....	33.75	34.25	35.5	36.5	33.5	34.5	.....	.....	11
12	.....	.....	34.5	35.	35.5	36.5	32.5	33.5	.....	.....	12
13	.....	.....	34.5	35.	[1]	[1]	31.	32.	.....	.....	13
14	.....	.....	35.	35.5	36.	36.5	31.	32.	.....	.....	14
15	.....	.....	[1]	[1]	36.	37.	31.	32.	.....	.....	15
16	.....	.....	35.5	36.5	36.5	37.	31.	32.	.....	.....	16
17	.....	.....	36.	37.	36.5	37.	[1]	[1]	.....	.....	17
18	.....	.....	37.	38.	36.5	37.	31.5	32.5	.....	.....	18
19	.....	.....	37.	38.	36.5	37.	33.	33.5	.....	.....	19
20	.....	.....	36.	36.5	[1]	[1]	32.5	34.5	.....	.....	20
21	.....	.....	35.	36.	36.5	37.	[3]	[3]	.....	.....	21
22	.....	.....	[1]	[1]	36.5	37.5	33.5	34.5	.....	.....	22
23	.....	.....	35.75	36.5	37.	38.	33.5	34.5	.....	.....	23
24	.....	.....	35.75	36.5	37.	38.	[1]	[1]	.....	.....	24
25	[1]		34.5	35.5	37.	38.	34.	34.5	.....	.....	25
26	.....	30.5	34.	35.	37.	38.	34.	35.	.....	.....	26
27	.....	32.	35.	36.	[1]	[1]	34.	35.	.....	.....	27
28	.....	33.5	35.	36.	37.	38.	34.5	35.	.....	.....	28
29	.....	34.5	[1]	[1]	37.	38.	35.	35.5	.....	.....	29
30	.....	34.5	35.	36.5	[2]	[2]	35.	35.5	.....	.....	30
31	33.5	34.	.....	.....	37.	38.	.....	.....	.....	.....	31
Av.	33.2		35.3		36.6		34.4		36.1		Av.

[1] Sunday. [2] Holiday. [3] Not quoted.

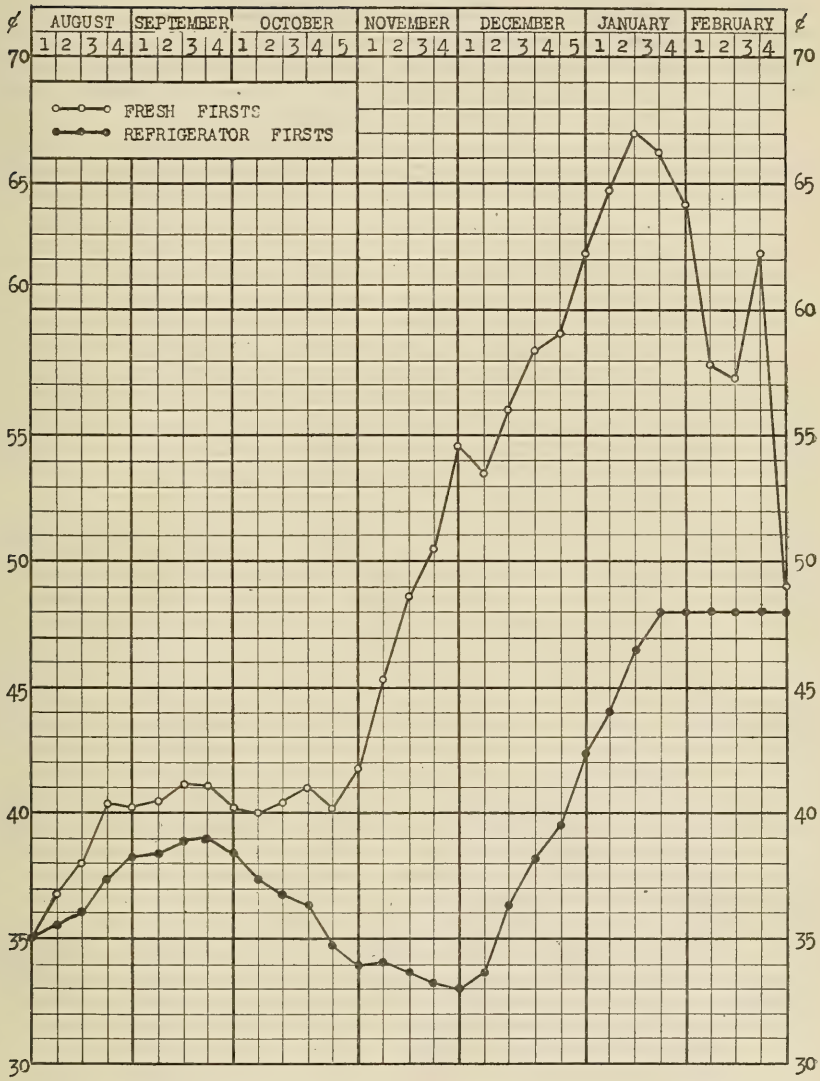

Fig. 9.—Comparative weekly average prices of "fresh firsts" and "refrigerator firsts" eggs on the New York market for season 1917-1918. Compiled from the Producers' Price-Current.

The movement into storage was so slow that by the first of May less than 30 per cent of the season's holdings had been stored instead of the 41 per cent of the previous season and the 49.5 per cent of the ten-year average of the Associated Warehouses. This 30 per cent was stored at an average cost of more than 35 cents per dozen. The 43 per cent stored during May cost 36.6 cents per dozen. The average cost as shown in Table 27 for the total holdings of 6,602,711 cases was 35.6 cents or a total cost of $70,560,532.

Table 27.—Cost of "storage packed firsts" case eggs placed in cold storage during season 1917-1918 if bought at New York market prices.

Date.	Percentage of total holdings.	Moved into storage.	Price per dozen.	Cost.
	Per cent.	Dozens	Cents.	Dollars.
March	2.8	5,546,277	33.2	1,841,364
April	26.7	52,887,715	35.3	18,669,363
May	43.0	85,174,972	36.6	31,174,040
June 1–15	13.2	26,146,736	35.0	9,151,358
June 16–30	11.5	22,779,353	33.9	7,722,201
July	2.8	5,546,277	36.1	2,002,206
Total	100.0	198,081,330	35.6	$70,560,532

Table 28 shows the daily quotations also compiled from the Producers' Price-Current of "refrigerator firsts," storage and insurance paid, on the New York market from August 6, 1917, to February 17, 1918, inclusive.

It will be observed that the distribution of the season's holdings began at 35 cents per dozen on August 6, the average price during the month being 36.8 cents. The average price rose to 38.7 cents in September, and then gradually dropped until December 1. The average during the latter half of November was only 33.3 cents. The severe winter caused a shortage in the fresh stock, resulting in a rise in price in the storage stock, and the average price during December was 37 cents and during January 44 cents. On January 10 and 12 the Food Administration wired the exchanges placing certain restrictions on the advance in prices. After January 17 there were no formal quotations, but the trade generally interpreted the attitude of the Food Administrator as authorizing the distribution of the remaining storage stocks at approximately 48 cents.

Table 28.—Prices of "refrigerator firsts" case eggs on the New York market for season 1917-1918.

[Compiled from The Producers' Price-Current.]

Date.	August.		September.		October.		November.		December.		January.		Date.
	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	Low.	High.	
	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	Cents.	
1	.....	.....	38.	38.5	37.	38.	33.5	34.	33.	34.	[2]	[2]	1
2	.....	.....	[1]	[1]	37.	38.	34.	34.5	[1]	[1]	41.5	42.5	2
3	.....	.....	[3]	[3]	37.	38.	34.	34.5	33.	34.	42.	42.5	3
4	.....	.....	38.	38.5	37.	38.	[1]	[1]	33.	34.	42.	43.	4
5	.....	.....	38.	38.5	37.	38.	34.	34.5	33.	34.	42.	43.	5
6	35.	35.5	38.	39.	36.5	37.5	[3]	[3]	33.5	34.	[1]	[1]	6
7	35.	35.5	38.	39.	[1]	[1]	33.5	34.5	33.5	34.5	43.	43.5	7
8	35.	35.5	38.	39.	36.	37.	33.5	34.5	33.5	34.5	43.	44.	8
9	35.5	36.	[1]	[1]	36.	37.	33.5	34.5	[1]	[1]	43.5	44.5	9
10	35.5	36.	38.	39.	36.5	37.	[3]	[3]	34.5	35.5	44.	45.	10
11	35.5	36.	38.5	39.5	36.5	37.5	[1]	[1]	35.	36.	44.	45.	11
12	[1]	[1]	38.5	39.5	[3]	[3]	[3]	[3]	36.	37.	44.	45.	12
13	35.5	36.	38.5	39.5	36.5	37.5	34.	34.5	36.	37.	[1]	[1]	13
14	35.5	36.5	38.5	39.5	[1]	[1]	33.5	34.5	36.5	37.5	45.5	46.5	14
15	36.	36.5	[3]	[3]	36.5	37.5	[3]	[3]	37.	37.5	46.	47.	15
16	36.	36.5	[1]	[1]	36.5	37.5	32.5	34.	[1]	[1]	46.	47.	16
17	36.	37.	38.5	39.5	36.	37.	32.5	33.5	38.	39.	48.	49.	17
18	36.	37.	38.5	39.5	35.5	36.5	[1]	[1]	38.	39.	[3]	[3]	18
19	[1]	[1]	38.5	39.5	35.5	36.	33.	34.	38.	39.	[3]	[3]	19
20	36.	37.	38.5	39.5	35.5	36.	33.	34.	38.	39.	[1]	[1]	20
21	37.	37.5	38.5	39.5	[1]	[1]	33.	34.	37.	38.	.....	.....	21
22	37.	37.5	38.5	39.5	35.	35.5	32.5	34.	37.	38.	.....	.....	22
23	37.	38.	[1]	[1]	34.	35.	32.5	33.5	[1]	[1]	.....	.....	23
24	37.5	38.	38.5	39.5	[3]	[3]	32.5	33.5	37.5	38.5	.....	.....	24
25	37.5	38.	38.5	39.5	.....	35.	[1]	[1]	[2]	[2]	.....	.....	25
26	[1]	[1]	38.	39.	34.75	35.	32.5	33.5	38.	39.	.....	.....	26
27	38.	38.5	37.5	38.5	34.	34.5	33.	34.	39.	40.	.....	.....	27
28	38.	38.5	37.5	38.5	[1]	[1]	33.	34.	40.	40.5	.....	.....	28
29	38.	38.5	37.5	38.5	33.	34.	[3]	[3]	41.	42.	.....	.....	29
30	38.	38.5	[1]	[1]	33.5	34.	33.	34.	[1]	[1]	.....	.....	30
31	38.	38.5	.....	.....	33.5	34.	.....	.....	41.5	42.5	.....	.....	31
Ave.	36.8		38.7		36.1		33.7		37.0		44.0		Ave.

[1] Sunday. [2] Holiday. [3] Not quoted.

It is believed that so much of the 200,000 cases remaining on February 1 as were placed on the market sold at about that price. Table 29 shows the value of the monthly decreases in holdings based on the New York market prices.

Table 29.—Selling price of "refrigerator firsts" case eggs delivered from cold storage during season 1917-1918 if sold at New York market prices.

Date.	Percentage of total holdings.	Moved out of storage.	Price per dozen.	Selling price.
	Per cent.	Dozens.	Cents.	Dollars.
August	8.4	16,638,832	36.8	6,123,090
September	8.4	16,638,832	38.7	6,439,228
October	16.4	32,485,337	36.1	11,727,207
November 1-15	11.8	23,373,597	34.1	7,970,397
November 16-30	13.2	26,146,736	33.3	8,706,863
December 1-15	12.6	24,958,248	34.9	8,710,429
December 16-30	12.1	23,967,841	39.1	9,371,426
January	15.0	29,712,199	44.0	13,073,368
February	2.1	4,159,708	48.0	1,996,660
Total	100.0	198,081,330	37.4	$74,118,668

The average selling price thus obtained was 37.4 cents per dozen and the total sales value $74,118,668. This shows a gross profit of 1.8 cents per dozen or $3,558,136. If allowance of 4 cents per dozen is made as covering storage, insurance and shrinkage for the season, (the figure commonly accepted in the trade), there would appear to have been a net loss of 2.2 cents per dozen or $4,365,117, aside from the interest on the investment.

The holdings of the season 1916-1917 proved a very profitable investment. The 6,060,129 cases held that season were stored at an average price of 23.44 cents, a total cost of $42,610,154, and sold at an average price of 32.98 cents, or $59,956,025, a gross profit of 9.54 cents or $17,345,871. The actual profit after deducting 4 cents a dozen for storage, insurance and shrinkage, amounted to 5.54 cents a dozen or $10,073,716, from which must be deducted the interest on the investment to secure the net profit.

In the season of 1915-1916, 6,084,529 cases were placed in cold storage at an average price of 20.82 cents or a total cost of $38,003,968. They were sold at 23.41 cents or $42,740,045 with an apparent profit of 2.59 cents per dozen, but an actual net loss of 1.41 cents or $2,565,358 and interest, if an allowance of 4 cents per dozen be made for storage, insurance and shrinkage. Figure 8 shows the average weekly prices on the New York Market for the last three seasons and figure 9 shows the comparative prices of "refrigerator firsts" and "fresh firsts" for the time of distribution of the 1917-1918 storage stocks.

Figure 10 shows the comparative New York and Chicago "storage firsts" and prices for "refrigerator firsts" during the 1917-1918 season. The Chicago prices are taken from the Daily Trade Bulletin.

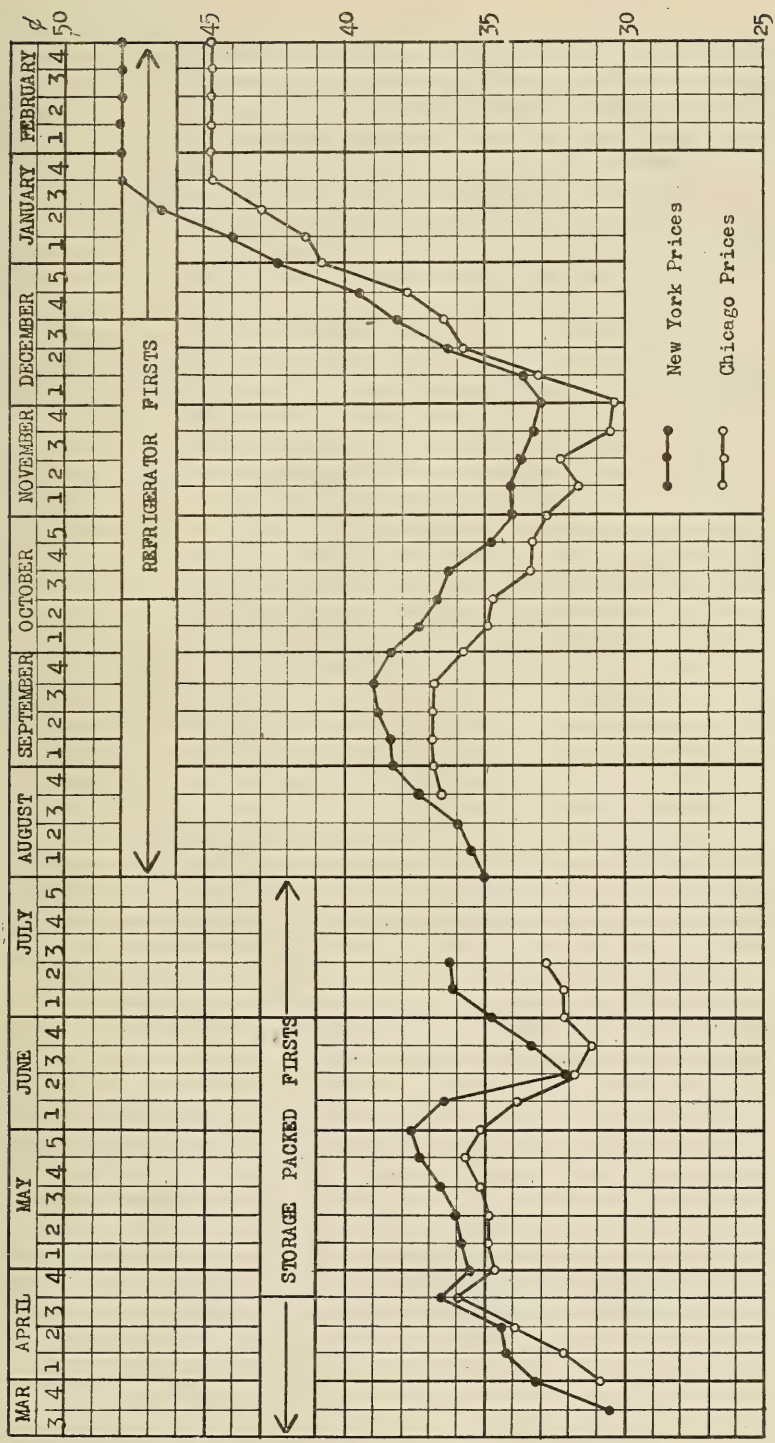

Fig. 10.—Comparative weekly prices of cold storage eggs on the New York and Chicago markets. Compiled from Producers' Price-Current and Daily Trade Bulletin.

According to the prices quoted on the New York market, if that portion of the public which purchased the cold storage eggs for the season had purchased fresh eggs instead, the 6,602,711 cases which they bought for $74,118,668 would have cost them $99,593,511 or $25,474,843 more than they paid for the storage stock. While it is true that many people could not have afforded the fresh eggs at the prices quoted and the consumption would have been reduced, it is also true that the increased demand, on account of the smaller supply available, had there been no storage stock, would no doubt have sent prices much higher.

Table 30.—Value of case eggs distributed from cold storage during 1917-1918 season at prices for which fresh eggs were sold during same period on New York market.

Date.	Percentage of total holdings.	Moved out of storage.	Price per dozen.	Selling price.
	Per cent.	Dozens.	Cents.	Dollars.
August	8.4	16,638,832	38.2	6,356,034
September	8.4	16,638,832	39.8	6,622,255
October	16.4	32,485,337	40.7	13,221,532
November 1	11.8	23,373,597	44.9	10,494,745
November 15	13.2	26,146,736	51.6	13,491,716
December 1	12.6	24,958,248	54.8	13,677,120
December 15	12.1	23,967,841	58.8	14,093,091
January	15.0	29,712,199	64.8	19,253,505
February	2.1	4,159,708	57.3	2,383,513
Total	100.0	198,081,330	50.3	$99,593,511

It is also apparent that, lacking storage facilities, the eggs that were placed in cold storage would otherwise have been disposed of through consumptive channels during the season of production and probably would have caused a substantial reduction in the prices at that time. There is, of course, no means of ascertaining the actual reduction that would have occurred, but it is probable that in many cases the prices would not have covered the cost of production.

REVIEW OF THE 1917-1918 SEASON FOR COLD STORAGE OF FROZEN EGGS.

The first report of the Bureau of Markets showing holdings of frozen eggs was issued on May 1, 1917. Reports were received from 125 cold storage plants, and their holdings were 2,659,380 pounds. The stocks gradually increased until September 1, when 165 warehouses reported 18,099,262 pounds. This was nearly three times as many pounds as were stored on the same date of the previous year. Table 31 shows the holdings of these firms segregated by sections and the holdings of 91 storages compared with the amount held by them in the previous season.

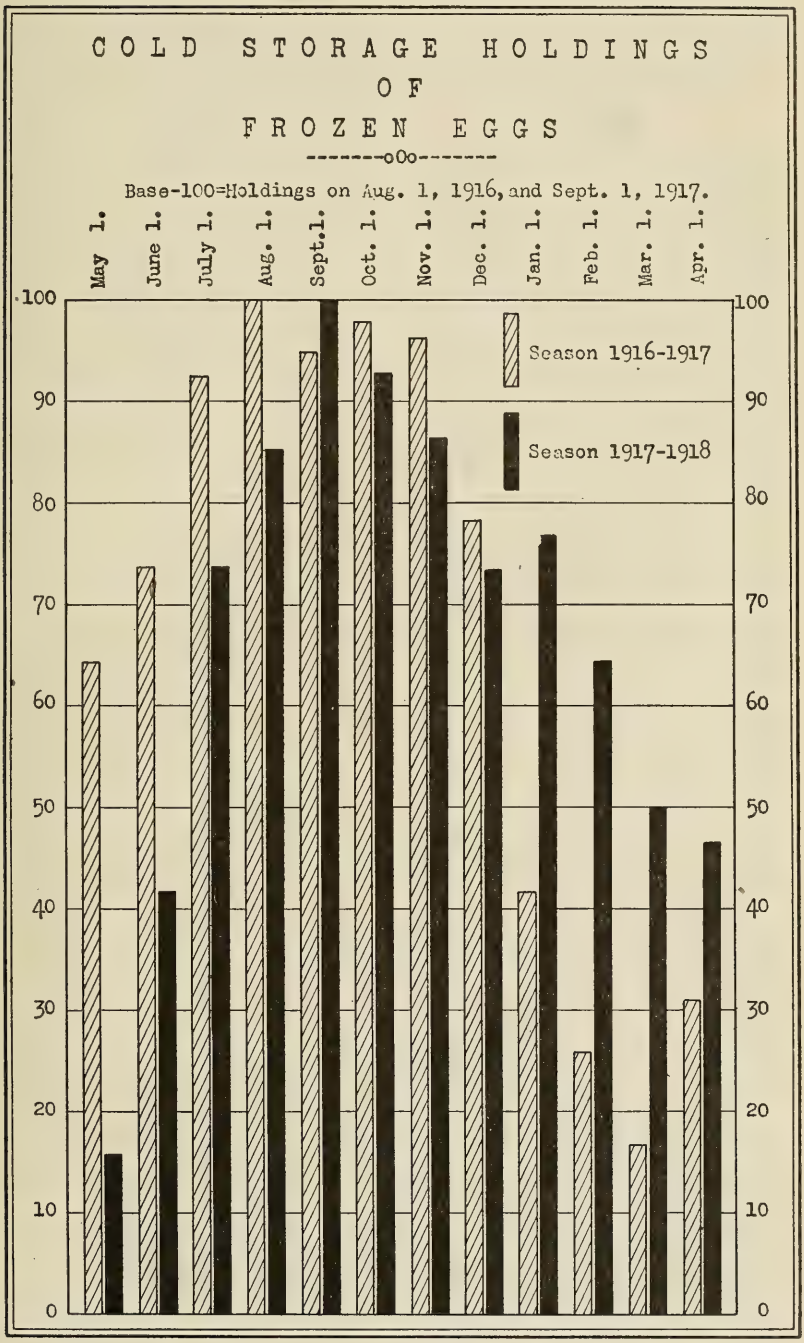
COLD STORAGE HOLDINGS
OF
FROZEN EGGS
Base-100=Holdings on Aug. 1, 1916, and Sept. 1, 1917.
May 1.
June 1.
July 1.
Aug. 1.
Sept. 1.
Oct. 1.
Nov. 1.
Dec. 1.
Jan. 1.
Feb. 1.
Mar. 1.
Apr. 1.
Season 1916-1917
Season 1917-1918
100
90
80
70
60
50
40
30
20
10
0

Fig. 11.

Table 31.—Cold storage holdings of frozen eggs as reported on September 1, 1917.

Section.	Reported for September 1, 1917.			Comparison with September 1, 1916.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	September 1, 1916.	September 1, 1917.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	7	680,066	3.8	5	55,595	59,116	+ 6.3
Middle Atlantic	35	7,958,620	44.0	12	1,481,083	1,481,083	—397.3
South Atlantic	8	168,004	0.9	–	–	–	–
North Central (E)	39	4,262,022	23.5	24	2,372,730	3,178,399	— 34.0
North Central (W)	45	4,081,644	22.5	30	999,437	3,436,913	+243.9
South Central	12	122,176	0.7	8.	14,083	50,866	+261.2
Western (N)	10	281,352	1.6	6	140,059	90,176	— 35.6
Western (S)	9	545,378	3.0	6	160.499	527,045	+228.4
Total	165	18,099,262	100.0	91	5,223,486	14,708,351	+181.6

There were 6,585,202 pounds or 37.9 per cent of the total amount stored in the city of New York. Chicago storages held 2,486,139 pounds or 13.7 per cent. Excepting in the city of New York a large proportion of the stock was stored in the producing sections. Of the 23.5 per cent held in the North Central East section only 13.7 per cent was held in Chicago, and in the North Central West only 5.2 per cent was stored in St. Louis compared with the 22.5 per cent held in the section. In the New England States only about 100,000 pounds were held outside of the city of Boston. Table 32 shows the increases and decreases in holdings compiled from the monthly report of the Bureau.

Table 32.—Monthly cold storage holdings of frozen eggs compared with previous month.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
April 1	126	2,347,461	1,267,715	+ 1,079,746	+ 85.2
May 1	135	3,025,336	2,473,288	+ 552,048	+ 22.3
June 1	104	5,837,822	2,474,936	+ 3,362,886	+135.9
July 1	105	12,043,948	6.843,068	+ 5,200,880	+ 76.0
August 1	117	14,429,516	12,495,458	+ 1,934,058	+ 15.5
September 1	116	16,592,263	14,444,844	+ 2,147,419	+ 14.9
October 1	144	16,373,472	17,908,958	— 1,535,486	— 8.6
November 1	159	15,862,051	16,913,124	— 1,051,073	— 6.2
December 1	162	12,707,627	15,227,195	— 2,519,568	— 16.5
January 1	161	13,706,339	12,784,169	+ 922,170	+ 7.2
February 1	161	11,731,551	14,050,137	— 2,318,586	— 16.5
March 1	181	9,775,736	12,297,758	— 2,522,022	— 20.5
April 1	177	8,834,115	9,750,792	— 916,677	— 9.4

Figure 11 shows the relative monthly holdings from May 1 to April 1 for the past two seasons. It will be observed that the greatest increases for this season were during May and June, the holdings decreasing during September, October, November, January and February, but showing a decided increase during December.

The slowness of the decrease in the holdings during this season is probably accounted for by the shortage in the sugar supply resulting in the decrease in the use of frozen eggs by the bakers. It is also possible that the low prices received for cold storage eggs led some dealers to break out and freeze them.

There were large importations of frozen and dried eggs during the season. Table 33 shows the importations from June, 1916, to March, 1918, as compiled from the reports of the Department of Commerce. Figures previous to that date are not available.

Table 33.—Monthly importations of frozen and dried eggs and yolks of eggs.

Month.	1916-1917.	1917-1918.
	Pounds.	Pounds.
April	.....	1,053,774
May	.....	1,022,371
June	.....	1,332,584
July	513,583	1,101,327
August	349,585	2,555,800
September	1,079,210	2,033,528
October	1,392,714	1,187,447
November	261,907	1,483,669
December	129,850	1,315,683
Janaury	820,078	606,384
February	500,375	502,191
March	1,861,743	1,450,494
Comparative totals	8,770,788	12,365,523
Grand totals	8,770,788	15,645,252

REVIEW OF REPORTS ON COLD STORAGE HOLDINGS OF FROZEN POULTRY.

The Bureau of Markets began securing reports showing the holdings of frozen poultry in cold storage on May 1, 1917. The reports show this product segregated into five different classifications, viz., broilers, roasters, fowls, turkeys, and miscellaneous poultry. The first four varieties are segregated according to classifications generally used by the trade and all others are classified as miscellaneous.

The reports received for several months were rather unsatisfactory owing to the difficulties encountered by the cold storage warehouses in segregating the poultry held into these different classifications. During this period the holdings of the storages that were unable to segregate were also included with miscellaneous poultry. Table 34 shows the number of pounds of each variety reported monthly to the Bureau from July, 1917, to June, 1918, inclusive, and figure 12 shows the comparative percentage that each variety is of the total amounts reported each month for the season of 1917-1918. For the first half of the season these percentages are of value only in showing the progress made in securing the proper segregations. In the latter part of the season they show the actual percentages of the different varieties stored as the segregations were then satisfactorily made by practically all of the cold storage warehouses.

Table 34.—Monthly holdings of frozen poultry for season 1917-1918.

Date.	Total holdings.	Broilers.	Roasters.	Fowls.	Turkeys.	Misc. poultry.
	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
July	55,704,435	3,769,671	5,231,397	2,033,018	3,639,182	41,031,167
August	50,125,012	3,555,594	4,962,127	1,860,764	3,558,683	36,187,844
September	32,596,250	2,517,336	3,897,323	1,258,923	3,193,483	41,729,185
October	45,608,617	3,405,894	3,275,639	2,021,332	3,404,313	33,501,439
November	52,557,223	5,074,028	5,160,063	3,269,014	6,485,291	32,568,827
December	49,749,819	8,877,926	12,307,964	8,649,707	3,298,063	16,616,159
January	63,495,687	9,050,855	16,598,683	13,219,137	4,577,367	20,049,645
February	67,729,215	8,250,415	17,978,167	15,090,069	10,515,828	15,894,736
March	57,251,341	7,383,141	14,486,271	12,622,601	9,824,560	12,934,768
April	43,834,616	4,796,790	11,523,853	9,165,095	8,614,438	9,734,440
May	26,553,783	3,144,835	6,974,239	4,957,940	6,490,759	4,986,010
June	18,905,632	1,720,069	3,921,708	2,716,634	5,935,480	4,611,741

Although the Bureau did not begin issuing reports until May 1, 1917, in sending out the monthly inquiries, information was also requested as to the amount in storage on the same date the previous year. The data thus obtained, however, were very incomplete as many firms had no records from which to report their holdings for the season of 1916-1917. Figure 13 shows the relative monthly holdings for the season of 1916-1917 and 1917-1918. It will be observed that the largest holdings were in storage on January 1, 1917, and that the carry-over was so great that on July 1, 1917, they were greater than on January 1, 1918, the date on which the largest holdings of that season would normally be expected. It is also quite probable that this large carry-over and possible ensuing losses to the dealers led to a much smaller quantity being placed in cold storage, the holdings being about one-third of those of the previous season.

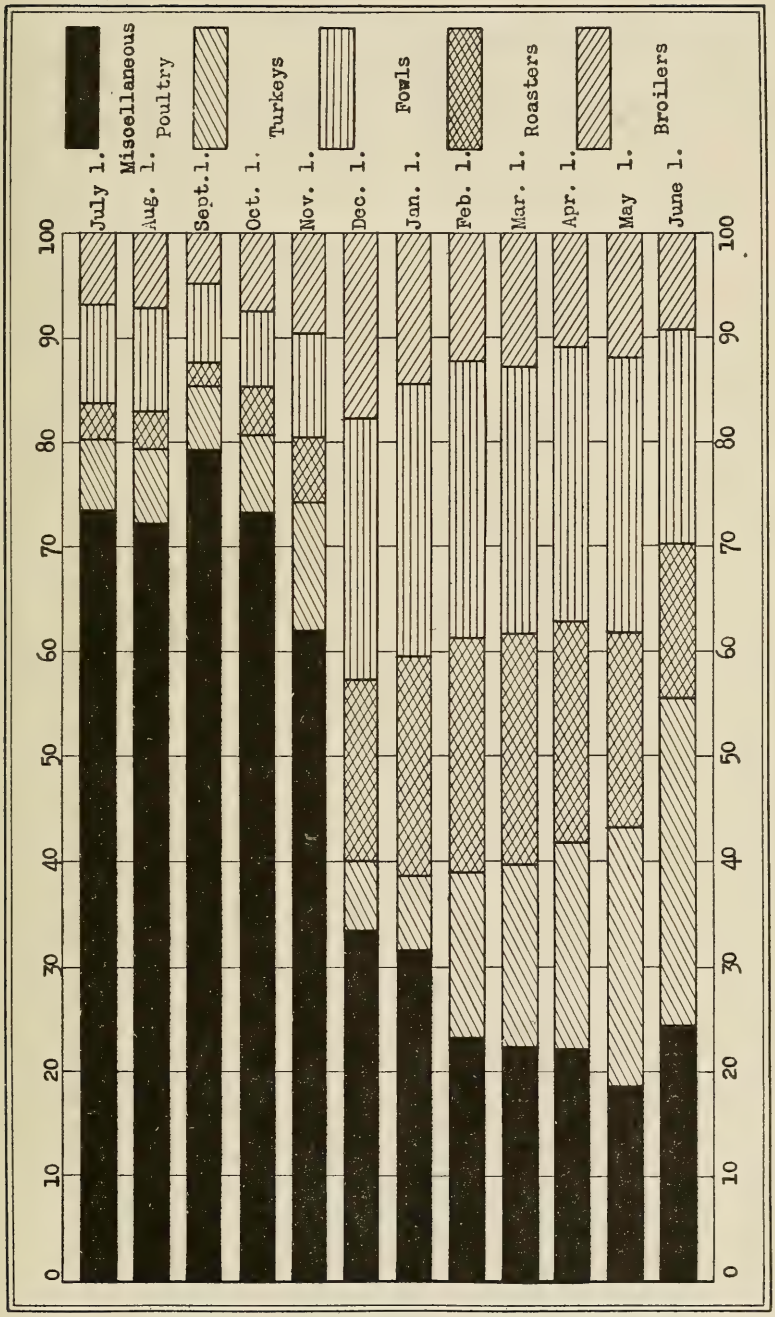

Fig 12.—Percentage of different varieties of frozen poultry stored monthly during season 1917-1918.

Table 35 shows the total holdings of frozen poultry on January 1, 1918, segregated by sections and a comparison of the holdings of the storages reporting for both seasons with their holdings of the previous season. Figure 14 shows graphically the comparative monthly holdings from July 1, 1917, to June 1, 1918, inclusive, and the proportionate quantities of the different varieties that were stored on the different dates.

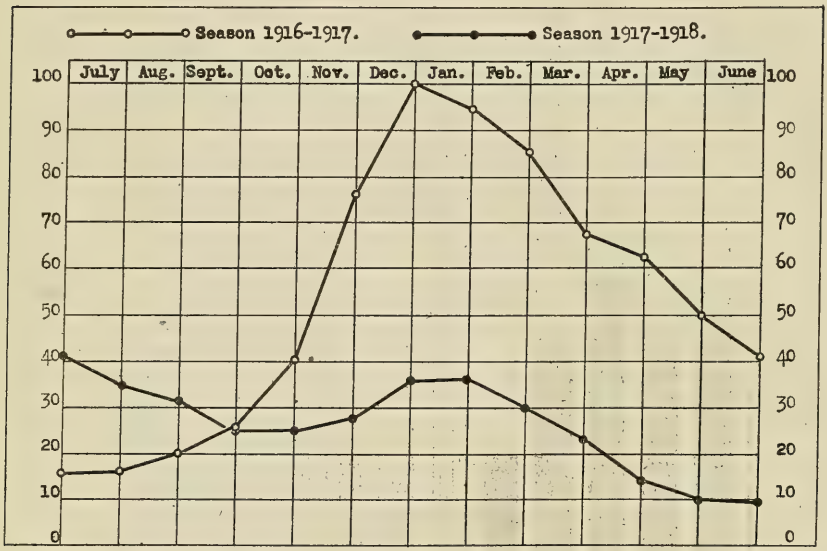

Fig. 13.—Relative monthly holdings of frozen poultry in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on January 1, 1917.)

Table 35.—Total cold storage holdings of frozen poultry as reported January 1, 1918.

Section.	Reported for January 1, 1918.		Comparison with January 1, 1917.		
			January 1, 1917.	January 1, 1918.	Decrease.
	Pounds.	Per cent.	Pounds.	Pounds.	Per cent.
New England	2,451,067	3.9	110,980	67,025	39.6
Middle Atlantic	16,193,219	25.5	3,721,003	1,394,529	62.5
South Atlantic	454,633	0.7	613,901	431,757	29.7
North Central (E)	31,969,989	50.4	10,068,570	6,969,941	30.8
North Central (W)	8,585,640	13.5	13,784,301	6,064,863	56.0
South Central	1,785,540	2.8	2,300,202	1,240,136	46.1
Western (N)	583,416	0.9	889,434	574,629	35.4
Western (S)	1,472,183	2.3	2,069,325	1,156,303	44.1
Total	63,495,687	100.0	33,557,716	17,899,183	46.7

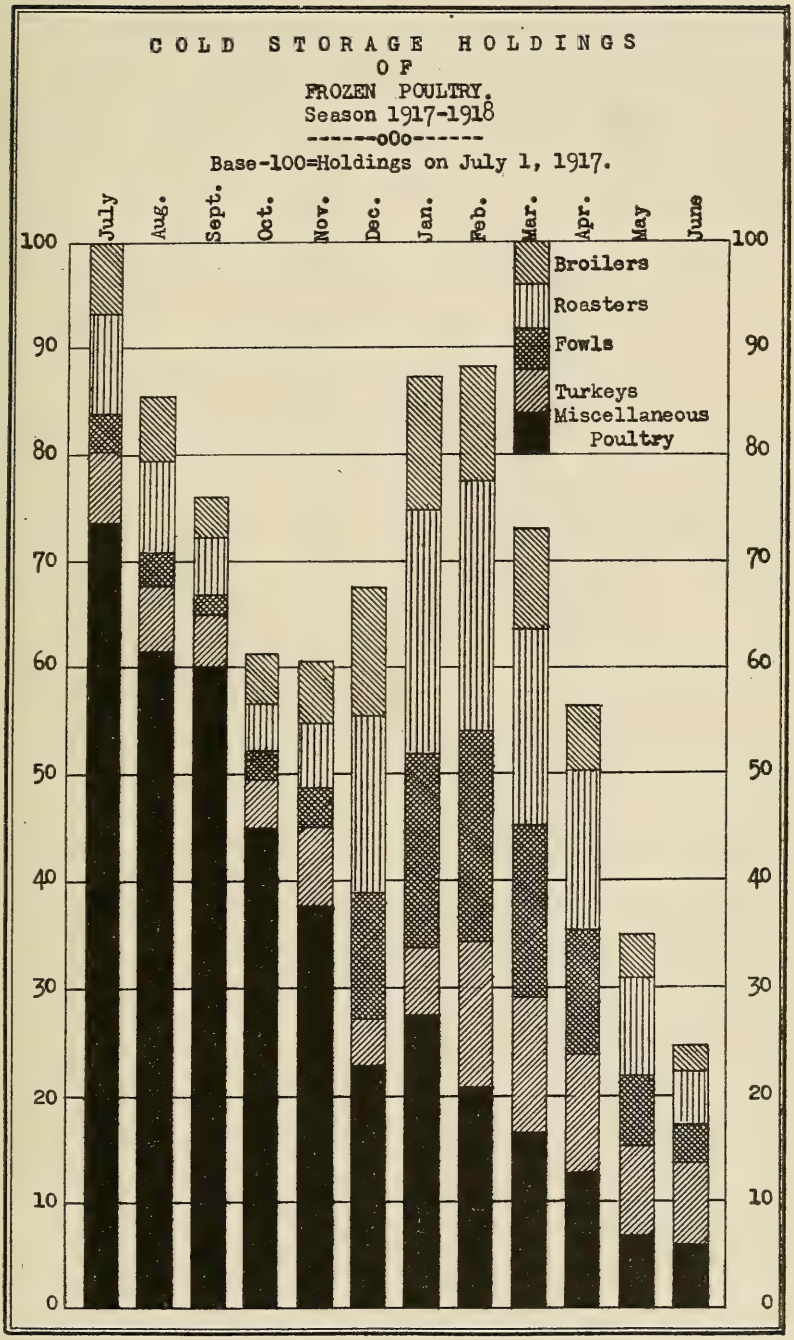
COLD STORAGE HOLDINGS
OF
FROZEN POULTRY.
Season 1917-1918
------ooo------
Base-100=Holdings on July 1, 1917.
July
Aug.
Sept.
Oct.
Nov.
Dec.
Jan.
Feb.
Mar.
Apr.
May
June
100
90
80
70
60
50
40
30
20
10
0
Broilers
Roasters
Fowls
Turkeys
Miscellaneous Poultry

Fig. 14.

Tables 36 to 40, inclusive, show the holdings on January 1 of all varieties except fowls, for which the holdings of February 1 are shown. The holdings of these dates do not show the actual peak loads of the season on account of the large carry over from the previous season. They represent, however, the peak load for the current season's stock, and as the segregation was very satisfactory at that time, they may be considered as representative of the quantities of the different varieties stored for the season.

Table 36.—Cold storage holdings of broilers as reported on January 1, 1918.

Section.	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	19	70,161	0.8	8	4,884	10,571	+116.4
Middle Atlantic	45	2,576,495	28.5	16	543,477	199,607	— 63.3
South Atlantic	9	93,751	1.0	6	161,498	84,683	— 47.6
North Central (E)	32	4,795,206	53.0	17	844,240	1,149,165	+ 36.1
North Central (W)	41	937,163	10.4	30	1,832,149	563,794	— 69.2
South Central	17	346,217	3.8	12	524,788	317,600	— 39.5
Western (N)	5	38,527	0.4	5	69,759	38,527	— 44.8
Western (S)	13	193,335	2.1	9	310,146	97,115	— 68.7
Total	181	9,050,855	100.0	103	4,290,941	2,461,062	— 42.6

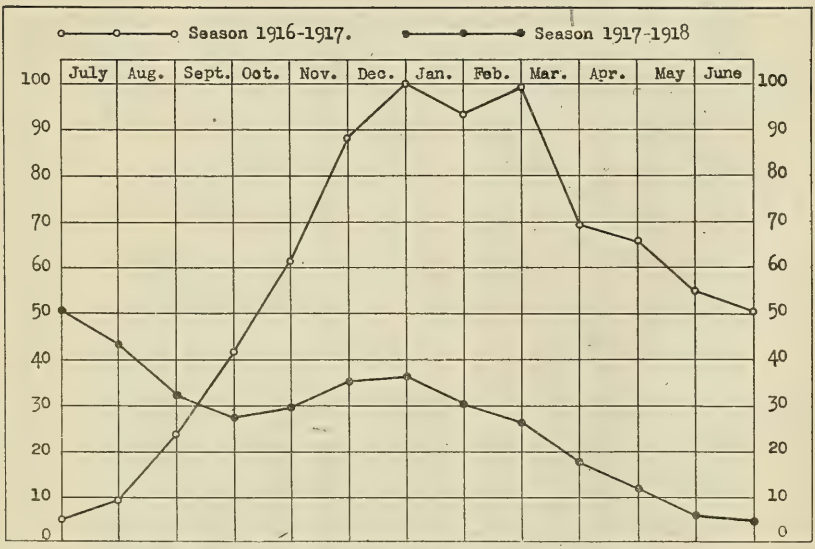

Fig. 15.—Relative monthly holdings of frozen broilers in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on January 1, 1917.)

Table 37.—Cold storage holdings of roasters as reported on January 1, 1918.

Section.	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	21	254,266	1.5	8	19,262	13,806	— 28.3
Middle Atlantic	44	4,255,155	25.6	15	692,709	275,796	— 60.2
South Atlantic	5	75,119	0.5	5	123,564	75,119	— 39.2
North Central (E)	33	9,133,360	55.0	17	1,535,090	2,486,424	+ 62.0
North Central (W)	42	2,522,763	15.2	29	4,020,729	2,016,804	— 49.8
South Central	14	208,618	1.3	11	393,643	198,612	— 49.5
Western (N)	6	87,587	0.5	6	47,264	87,587	+ 85.3
Western (S)	13	61,815	0.4	8	85,917	42,303	— 50.8
Total	178	16,598,683	100.0	99	6,918,178	5,196,451	— 24.9

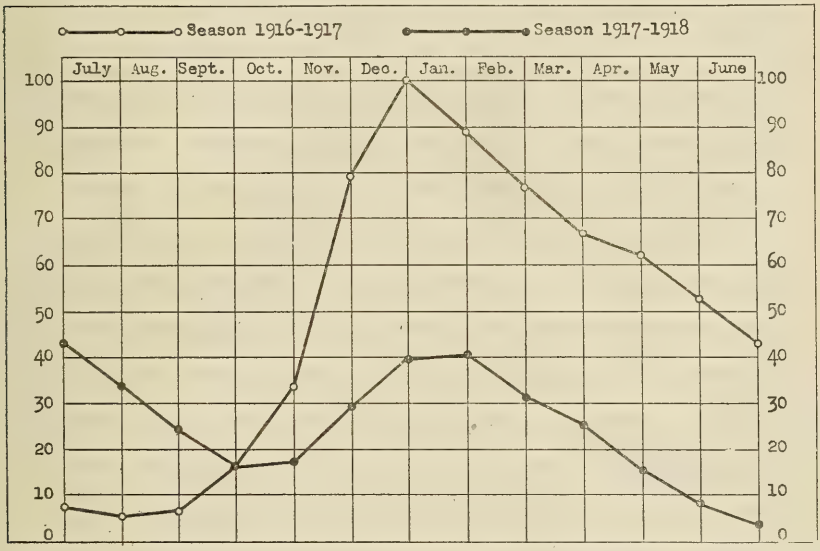

Fig. 16.—Relative monthly holdings of frozen roasters in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on January 1, 1917.)

Table 38.—Cold storage holdings of fowls as reported on February 1, 1918.

Section.	Reported for February 1, 1918.			Comparison with February 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	February 1, 1917.	February 1, 1918.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	29	1,217,175	8.1	16	174,139	98,652	— 43.3
Middle Atlantic	40	3,062,721	20.3	22	2,078,672	1,337,296	— 35.7
South Atlantic	11	58,430	0.4	10	68,286	56,609	— 17.1
North Central (E)	33	8,239,577	54.6	16	1,421,152	615,451	— 56.7
North Central (W)	41	1,577,954	10.4	33	3,612,228	1,254,588	— 65.3
South Central	15	458,829	3.0	12	475,293	395,040	— 16.9
Western (N)	14	163,862	1.1	10	140,576	159,983	+ 13.8
Western (S)	18	311,521	2.1	12	323,907	143,177	— 55.8
Total	201	15,090,069	100.0	131	8,294,253	4,060,796	— 51.0

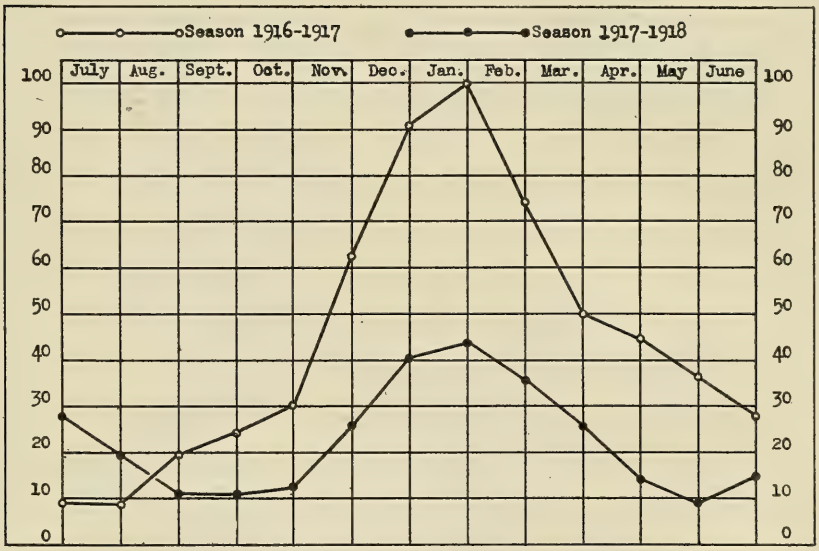

Fig. 17.—Relative monthly holdings of frozen fowls in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on February 1, 1917.)

Table 39.—Cold storage holdings of turkeys as reported on January 1, 1918.

Section	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918.	Decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	20	42,554	0.9	10	61,924	10,285	83.4
Middle Atlantic	48	910,633	19.9	21	399,247	65,836	83.5
South Atlantic	15	92,877	2.0	11	124,559	84,915	31.8
North Central (E)	35	2,200,489	48.1	18	675,880	532,481	21.2
North Central (W)	39	671,868	14.7	28	402,835	284,964	29.3
South Central	25	340,520	7.4	18	761.909	246,946	67.6
Western (N)	8	61,343	1.4	8	122.697	61,343	50.0
Western (S)	22	257,083	5.6	11	264,435	156,152	40.9
Total	212	4,577,367	100.0	125	2,813,486	1,442,922	48.7

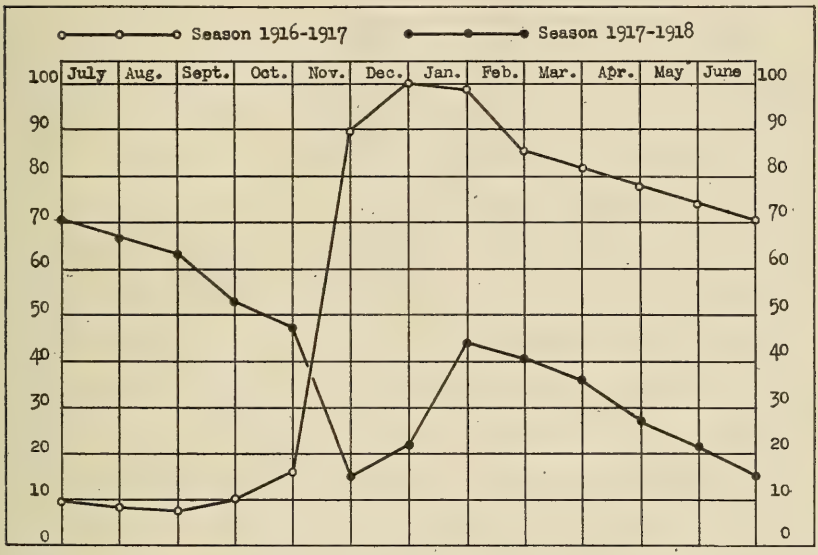

Fig. 18.—Relative monthly holdings of frozen turkeys in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on January 1, 1917.)

Table 40.—Cold storage holdings of miscellaneous poultry as reported on January 1, 1918.

Section.	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918.	Increase or decrease.
	Number.	Pounds.	Per cent.	Number.	Pounds.	Pounds.	Per cent.
New England	26	1,835,341	9.2	11	8,213	2,095	— 74.5
Middle Atlantic	62	6,121,836	30.5	28	1,475,669	683,991	— 53.6
South Atlantic	11	73,785	0.4	9	126,389	71,857	— 43.1
North Central (E)	48	7,842,706	39.1	25	5,495,957	1,735,308	— 68.4
North Central (W)	55	2,809,869	14.0	40	4,694,655	1,952,976	— 58.4
South Central	23	403,644	2.0	15	67,604	79,015	+ 16.9
Western (N)	10	285,701	1.4	9	547.012	279,,241	— 49.0
Western (S)	19	676,763	3.4	14	1,081,844	640,689	— 40.8
Total	254	20,049,645	100.0	151	13,497,343	5,445,172	— 59.7

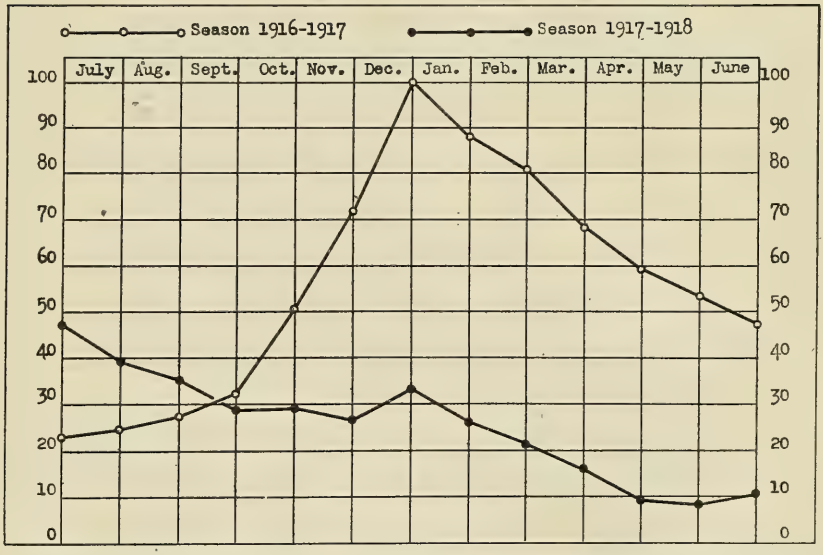

Fig. 19.—Relative monthly holdings of miscellaneous frozen poultry in cold storage during seasons of 1916-1917 and 1917-1918. (Base 100 equals holdings on January 1, 1917.)

Tables 41 to 46, inclusive, show the holdings of each month compared with those of the preceding month for the 1917-1918 season. These comparative holdings and the percentages of increase and decrease are based in each case on the holdings of the storages that reported for both months.

Table 41.—Monthly cold storage holdings of broilers for season 1917-1918 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	104	2,206,197	3,571,691	— 1,365,494	— 38.2
September 1	100	2,457,563	2,910,416	— 452,853	— 15.6
October 1	112	1,915,446	2,467,992	— 552,546	— 22.4
November 1	120	3,637,273	3,375,672	+ 261,601	+ 7.7
December 1	133	5,725,862	4,892,364	+ 833,498	+ 17.0
January 1	153	7,695,795	7,743,787	— 47,992	— 0.6
February 1	167	7,909,192	8,836,899	— 927,707	— 10.5
March 1	186	7,085,346	8,249,366	— 1,164,020	— 14.1
April 1	187	4,784,657	7,301,237	— 2,516,580	— 34.5
May 1	184	3,125,769	4,656,790	— 1,531,021	— 32.9
June 1	193	1,720,069	3,138,005	— 1,417,936	— 45.2
July 1	187	1,311,800	1,717,404	— 405,604	— 23.6

Table 42.—Monthly cold storage holdings of roasters for season 1917-1918 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	105	3,329,372	5,142,147	— 1,182,775	— 35.3
September 1	95	3,798,483	4,742,043	— 943,560	— 19.9
October 1	98	2,576,421	3,849,008	— 1,272,587	— 33.1
November 1	111	3,495,190	3,247,149	+ 248,041	+ 7.6
December 1	125	8,307,369	4,933,848	+ 3,373,521	+ 68.4
January 1	151	15,836,843	11,859,380	+ 3,977,463	+ 33.5
February 1	160	16,907,231	16,473,015	+ 434,216	+ 2.6
March 1	175	13,964,889	17,973,428	— 4,008,539	— 22.3
April 1	177	11,441,882	14,284,631	— 2,842,749	— 19.9
May 1	182	6,912,760	11,465,913	— 4,553,153	— 39.7
June 1	194	3,914,942	6,971,801	— 3,056,859	— 43.8
July 1	186	2,320,322	3,922,071	— 1,601,749	— 40.8

Table 43.—Monthly cold storage holdings of fowls for season 1917-1918 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	108	1,712,420	1,905,856	— 193,436	— 10.1
September 1	104	1,323,367	1,809,457	— 486,090	— 26.9
October 1	110	1,225,924	1,239,743	— 13,819	— 1.1
November 1	125	2,176,705	1,971,430	+ 205,275	+ 10.4
December 1	141	6,703,811	3,158,204	+ 3,545,607	+112.3
January 1	160	12,640,548	8,062,355	+ 4,578,193	+ 56.8
February 1	167	13,996,710	13,027,435	+ 969,275	+ 7.4
March 1	189	12,195,985	15,081,181	— 2,885,196	— 19.1
Arpil 1	205	9,218,182	12,519,027	— 3,300,845	— 26.4
May 1	205	4,913,705	9,110,249	— 4,196,544	— 46.1
June 1	211	2,707,640	4,115,966	— 1,408,326	— 34.2
July 1	205	4,233,976	2,708,272	+ 1,525,704	+ 56.3

Table 44.—Monthly cold storage holdings of turkeys for season 1917-1918 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	107	3,180,131	3,504,521	— 324,390	— 9.3
September 1	102	3,050,118	3,443,601	— 393,483	— 11.4
October 1	108	2,620,729	3,136,508	— 515,779	— 16.4
November 1	121	2,994,044	3,324,722	— 330,678	— 9.9
December 1	131	2,019,048	6,399,075	— 4,380,027	— 68.4
January 1	170	4,321,615	2,954,272	+ 1,367,343	+ 46.3
February 1	190	9,071,953	4,500,654	+ 4,571,299	+101.6
March 1	214	9,637,205	10,503,524	— 866,319	— 8.2
April 1	214	8,573,832	9,737,875	— 1,164,043	— 12.0
May 1	210	6,474,143	8,599,939	— 2,125,796	— 24.7
June 1	205	5,934,887	7,317,169	— 1,382,282	— 18.9
July 1	197	4,233,456	5,906,699	— 1,673,243	— 28.3

Table 45.—Monthly cold storage holdings of miscellaneous poultry for season 1917-1918 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	153	35,602,249	39,731,499	— 4,129,250	— 10.4
September 1	153	31,995,244	35,077,131	— 3,081,887	— 8.8
October 1	171	32,729,238	40,310,178	— 7,580,940	— 18.8
November 1	190	32,421,891	33,226,460	— 804,569	— 2.4
December 1	190	7,816,416	8,104,946	— 288,530	— 3.6
January	211	18,239,448	14,780,241	+ 3,459,207	+ 23.4
February 1	224	15,439,245	19,767,286	— 4,328,041	— 21.9
March 1	235	12,566,909	15,151,338	— 2,584,429	— 17.1
April 1	243	9,672,387	12,905,018	— 3,232,631	— 25.0
May 1	238	4,975,171	8,694,017	— 3,718,846	— 42.8
June 1	242	4,429,679	4,975,096	— 545,417	— 11.0
July 1	235	5,781,039	4,611,548	+ 1,169,491	+ 25.4

Table 46.—Monthly cold storage holdings of total frozen poultry for season 1917-1918 as compared with previous months.

Date.	Comparative holdings.		Increase or decrease.	
	Current month.	Preceding month.		
	Pounds.	Pounds.	Pounds.	Per cent.
August 1	46,030,369	53,855,714	— 7,825,345	— 14.5
September 1	42,624,775	47,982,648	— 5,357,873	— 11.2
October 1	41,067,758	51,003,429	— 9,935,671	— 19.5
November 1	44,725,103	45,145,433	— 420,330	— 0.9
December 1	30,572,506	27,488,437	+ 3,084,069	+ 11.2
January 1	58,734,249	45,400,035	+13,334,214	+ 29.4
February 1	63,324,331	62,605,289	+ 719,042	+ 1.1
March 1	55,450,334	66,958,837	—11,508,503	— 17.2
April 1	43,690,940	56,747,788	—13,056,848	— 23.0
May 1	26,401,548	42,526,908	—16,125,360	— 37.9
June 1	18,707,217	26,518,037	— 7,810,820	— 29.5
July 1	17,880,593	18,865,994	— 985,401	— 5.2

Tables 47 to 52, inclusive, show the same data for the season of 1916-1917. As previously stated, on account of the lack of reports from many warehouses these figures are very incomplete.

Table 47.—Monthly cold storage holdings of broilers for season 1916-1917 as compared with previous months.

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	58	317,135	178,571	+ 138,564	+ 77.6
September 1	49	440,556	243,166	+ 197,390	+ 81.2
October 1	65	1,099,604	661,589	+ 438,015	+ 66.2
November 1	81	2,007,799	1,272,953	+ 734,846	+ 57.7
December 1	84	3,135,704	2,112,296	+ 1,023,408	+ 48.5
January 1	86	3,720,338	3,376,080	+ 344,258	+ 10.2
February 1	90	3,903,888	4,177,467	— 273,579	— 6.5
March 1	105	4,301,277	4,146,388	+ 154,889	+ 3.7
April 1	111	3,143,788	4,337,197	— 1,193,409	— 27.5
May 1	113	3,429,852	3,562,298	— 132,446	— 3.7
June 1	134	4,387,479	5,104,412	— 716,933	— 14.0
July 1	135	4,237,654	4,940,446	— 702,792	— 14.2

Table 48.—Monthly cold storage holdings of roasters for season 1916-1917 as compared with previous months.

Date.	Storages reporting.	Comparative holdings. Current month.	Comparative holdings. Preceding month.	Increase or decrease.	
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	52	242,119	328,863	— 86,744	— 26.4
September 1	46	386,277	312,680	+ 73,597	+ 23.5
October 1	55	981,079	398,434	+ 582,645	+146.2
November 1	71	2,000,800	972,656	+ 1,028,144	+105.7
December 1	75	4,631,215	1,976,390	+ 2,654,825	+134.3
January 1	80	6,184,653	4,895,194	+ 1,289,459	+ 26.3
February 1	88	5,513,471	6,222,169	— 708,698	— 11.4
March 1	101	5,350,258	6,167,056	— 816,798	— 13.2
April 1	107	4,772,702	5,494,683	— 721,981	— 13.1
May 1	114	5,604,246	6,032,829	— 428,583	— 7.1
June 1	140	6,967,872	7,963,991	— 996,119	— 12.5
July 1	143	6,407,242	7,539,751	— 1,132,509	— 15.0

Table 49.—Monthly cold storage holdings of fowls for season 1916-1917 as compared with previous months.

Date	Storages reporting.	Comparative holdings. Current month.	Comparative holdings. Preceding month.	Increase or decrease.	
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	63	388,349	390,131	— 1,782	— 0.5
September 1	60	863,582	386,790	+ 476,792	+123.3
October 1	69	1,018,180	829,555	+ 188,625	+ 22.7
November 1	89	1,615,081	1,283,345	+ 331,736	+ 25.8
December 1	94	3,546,615	1,735,088	+ 1,811,527	+104.4
January 1	93	5,741,491	3,937,126	+ 1,804,365	+ 45.8
February 1	99	6,554,853	5,945,038	+ 609,815	+ 10.3
March 1	117	4,985,630	6,768,474	— 1,782,844	— 26.3
April 1	127	3,364,330	4,992,144	— 1,627,814	— 32.6
May 1	131	4,196,011	4,685,604	— 489,593	— 10.4
June 1	155	4,364,944	5,058,295	— 693,351	— 13.7
July 1	154	3,755,639	4,683,995	— 928,356	— 19.8

Table 50.—Monthly cold storage holdings of turkeys for season 1916-1917 as compared with previous months.

Date.	Storages reporting.	Comparative holdings. Current month.	Comparative holdings. Preceding month.	Increase or decrease.	
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	59	148,230	179,179	— 30,949	— 17.3
September 1	47	138,737	147,243	— 8,506	— 5.8
October 1	57	188,022	143,364	+ 44,658	+ 31.2
November 1	72	313,486	196,939	+ 116,547	+ 59.2
December 1	77	2,321,957	406,232	+ 1,915,725	+471.6
January 1	97	2,612,143	2,347,933	+ 264,210	+ 11.3
February 1	108	2,737,621	2,774,037	— 36,416	— 1.3
March 1	122	3,201,978	2,818,308	+ 383,670	+ 13.6
April 1	127	2,444,708	3,175,288	— 730,580	— 23.0
May 1	124	2,938,689	2,868,199	+ 70,490	+ 2.5
June 1	145	4,354,613	4,290,907	+ 63,706	+ 1.5
July 1	143	3,971,127	4,546,865	— 575,738	— 12.7

Table 51.—Monthly cold storage holdings of miscellaneous poultry for season 1916-1917 as compared with previous months.

Date.	Storages reporting.	Comparative holdings. Current month.	Comparative holdings. Preceding month.	Increase or decrease.	
	Number.	Pounds.	Pounds.	Pounds.	Per cent.
August 1	89	5,298,918	5,083,011	+ 215,907	+ 4.2
September 1	84	6,723,311	5,985,629	+ 737,682	+ 12.3
October 1	99	6,830,107	5,780,579	+ 1,049,528	+ 18.2
November 1	127	24,158,388	15,401,995	+ 8,756,393	+ 56.9
December 1	115	5,642,769	3,957,102	+ 1,685,667	+ 42.6
January 1	117	12,255,876	8,796,700	+ 3,459,176	+ 39.3
February 1	125	9,390,516	10,688,855	— 1,298,339	— 12.1
March 1	138	9,194,858	10,020,075	— 825,217	— 8.2
April 1	149	7,970,741	9,392,650	— 1,421,909	— 15.1
May 1	147	4,608,660	5,328,260	— 719,600	— 13.5
June 1	139	35,323,239	39,675,388	— 4,352,049	— 11.0
July 1	164	8,186,381	8,426,829	— 240,448	— 2.9

Table 52.—Monthly cold storage holdings of total frozen poultry for season 1916-1917 as compared with previous months.

Date.	Comparative holdings.		Increase or decrease.	
	Current month.	Preceding month.		
	Pounds.	Pounds.	Pounds.	Per cent.
August 1	6,394,751	6,159,755	+ 234,996	+ 3.8
September 1	8,552,463	7,075,508	+ 1,476,955	+ 20.9
October 1	10,116,992	7,813,521	+ 2,303,471	+ 29.5
November 1	30,095,554	19,127,888	+10,967,666	+ 57.3
December 1	19,278,260	10,187,108	+ 9,091,152	+ 89.2
January 1	30,514,501	23,353,033	+ 7,161,468	+ 30.7
February 1	28,100,349	29,807,566	— 1,707,217	— 5.7
March 1	27,034,001	29,920,301	— 2,886,300	— 9.6
April 1	21,696,269	27,391,962	— 5,695,693	— 20.8
May 1	20,777,458	22,477,190	— 1,699,732	— 7.6
June 1	55,398,147	62,092,993	— 6,694,846	— 10.8
July 1	26,558,043	30,137,886	— 3,579,843	— 11.9

Figures 15 to 19, inclusive, show the comparative monthly holdings and movement of each variety from July 1, 1916, to July 1, 1918. It is realized that the monthly holdings and increases and decreases in holdings as shown for these two seasons are probably abnormal and cannot be considered as representative of the average season.

DISTRIBUTION OF REPORTS.

The reports of storage holdings issued by the Bureau of Markets are distributed upon specific request to all firms or individuals desiring them. Application should be made to the Bureau of Markets, Department of Agriculture, Washington, D. C.

In addition to the detailed mail reports a brief summary of each is distributed free of charge through the branch offices of the Bureau. This summary does not contain as much information as the detailed report and is issued several days in advance of it. It is sent over the Bureau's leased wires to 34 branch offices in some of the more important cities throughout the United States. The following list of offices now publish monthly summaries: Atlanta, Buffalo, Birmingham, Boston, Butte, Chicago, Cincinnati, Cleveland, Columbus, Detroit, Denver, Des Moines, Fargo, Fort Worth, Houston, Indianapolis, Jacksonville, Kansas City, Lancaster, Memphis, Minneapolis, New Orleans, New York, Oklahoma City, Omaha, Philadelphia, Pittsburgh, Portland, St. Louis, St. Paul, Salt Lake City, San Francisco, and Spokane.

Any person or firm in these cities desiring this advance information may secure it by making arrangements with these offices direct. Persons in cities not having branch offices may request that it be sent them by telegraph, charges collect, thus receiving it at approximately the same time that it is published in Washington or in the branch offices.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 777

Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C. ▼ July 10, 1919

FATTENING STEERS ON SUMMER PASTURE IN THE SOUTH.

By W. F. Ward, *formerly in Animal Husbandry Division, Bureau of Animal Industry;* Dan T. Gray, *formerly Professor of Animal Husbandry, Alabama Polytechnic Institute; and* E. R. Lloyd, *Director of Mississippi Experiment Station.*[1]

THE experiments described in this bulletin required several years for completion, but in view of present opportunities for live stock in the South and efforts to reduce production costs, the results are of unusual current interest. The bulletin treats each experiment separately as follows:

PURPOSE OF WORK AND PREVIOUS EXPERIMENTS.

The producer of beef in the South depends largely on pasture for growing and finishing his cattle for market. A great variety of valuable pasture plants is found. Some of the plants make rapid growth early in the spring; others flourish later in the heat of summer; still others furnish abundant grazing in the fall. Coupled with these conditions is the smaller proportion of tillable land in the South than is found in the corn-belt States; that fact makes the area left for grazing proportionately more extensive. For these reasons sound information on the proper use of southern pasture lands for beef production is of more than average importance.

The first of a series of experiments in fattening steers on grass, conducted jointly by the Bureau of Animal Industry and the Alabama Experiment Station, was begun in 1908 and continued during each grazing period until 1913, inclusive. In 1915 similar work was commenced in Mississippi cooperatively with the Mississippi Experiment Station. Results of summer feeding to and including 1911,

[1] Acknowledgment is due G. A. Scott and S. W. Greene, of the Animal Husbandry Division, United States Department of Agriculture, for assistance in compiling this bulletin.

together with other experiments in wintering and dry-lot feeding of beef cattle, have been published.[1]

This bulletin is confined to reports of four summers' feeding—two in Alabama in 1912 and 1913 and two in Mississippi in 1915 and 1916. Each year's test is reported separately.

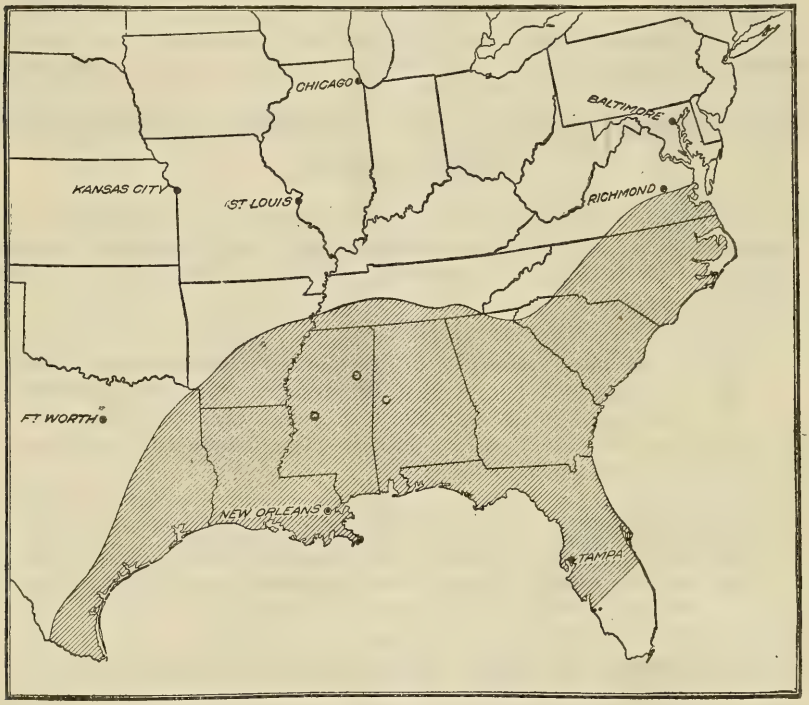

FIG. 1.—The shaded area represents the portion of the Southern States to which the results obtained in the feeding experiment are applicable. The unshaded portions within the shaded area represent coastal plain and piney-wood sections where soil and pasture conditions are different from those applicable to the experiment. The circles in Alabama and Mississippi show the approximate locations of the test farms. The locations of the various cattle markets to which southern cattle are shipped is also shown.

All tests were carried out under actual and typical farm conditions; consequently the results may be applied directly to the management and feeding of cattle on pasture in southern regions where climatic conditions and pasture grasses are similar to those of Sumter County, Ala., and Clay and Madison Counties, Miss., which will be described.

The experiments of 1912 and 1913 were conducted on the farm of O. E. Cobb, Sumterville, Sumter County, Ala., where several years' experimental work with beef cattle already had been done. The cattle, feed, and pastures were furnished by Mr. Cobb. The bureau employed S. S. Jerdan to have direct charge of the management and feeding and to keep records of the work.

[1] See Bureau of Animal Industry Bulletins 103, 147, and 159, and Department of Agriculture Bulletins 73, 110, 761, and 762.

I. FATTENING STEERS ON SUMMER PASTURE. ALABAMA, 1912.

OBJECTS AND PLAN OF THE EXPERIMENT.

The general plan of the work was similar to that followed in previous years. Usually the steers were purchased in the fall, carried through the winter, divided into lots in the spring, and put on pasture as soon as the grasses were well started. In this experiment most of the steers were purchased late in the spring and put on pasture late in May, with the intention of finishing them for market early in the fall.

The 90 steers available were divided and fed as follows:

Lot 1, 29 steers, pasture alone.
Lot 2, 25 steers, pasture and one-half corn chop and one-half cottonseed cake.
Lot 3, 36 steers, pasture and cottonseed cake.

The lots were purposely unequal in number to conform to the size of pasture used.

The objects of the experiment were (1) to continue the study of fattening steers on pasture; (2) to determine whether it is profitable to feed cottonseed cake to cattle on pasture; (3) to compare cottonseed cake with a ration of one-half cottonseed cake and one-half corn chop for finishing steers on pasture; and (4) to see which of the three methods is most profitable.

The steers of the three lots were chiefly grade Herefords, Shorthorns, and Aberdeen-Angus. A few were grade Red Polls. All were 2 and 3 year olds of fair quality.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed cake used in this test was nut size and of good quality, containing about 38 per cent crude protein. The advantages of feeding cake instead of meal are these: Rains do not make the cake unpalatable and winds do not blow it out of the feed bunks; the cake requires chewing, and greedy steers can not eat more than their share at the expense of the timid ones. When cottonseed meal is fed in open pastures, rain and wind are liable to cause waste; greedy steers bolt it and often get scours, which causes the animals to feed out unevenly.

The corn was shipped in and part of it was badly damaged. That fact must be considered when comparing the gains of the steers in lot 2 with those of the other lots. The cottonseed cake cost $28 a ton on the farm. The corn chop was charged to the steers of lot 2 at an average price of 85½ cents a bushel.

The character of the pasture lands and grasses is described in Department of Agriculture Bulletin 110, entitled "Fattening Cattle in Alabama," from which the following is quoted:

> The summer pastures used in these experiments consisted of a mixture of sweet clover (melilotus), Japan clover (lespedeza), Johnson grass, crab grass, and some Bermuda grass. The sweet-clover seed had been planted, but the other plants were purely voluntary. As a rule sweet clover becomes available for light grazing by March 15, while the Japan clover and Bermuda grass seldom afford good grazing before May 15.

Rains and showers were frequent throughout the summer, and abundant grazing was furnished by the pastures until September, when it became very dry. The pastures were charged to the steers at 50 cents a head for each period of 28 days.

METHOD OF FEEDING AND HANDLING THE CATTLE.

The three lots of steers were put on pasture May 28, 1912. The pastures had not been used for a month and were in fine condition. The steers were weighed at the beginning of the work and again at the end. As some of them were extremely wild, the former practice of weighing every 28 days was discontinued.

Lots 1 and 2 were supplied with good artesian water, while lot 3 had water only from pools in the pasture. All the cattle were salted once a week. The cattle of lot 1 had little attention other than salting. Lot 2 was fed once a day, about sundown, cottonseed cake and corn chop, and lot 3 was fed cottonseed cake in troughs placed in the pasture. The cattle went on feed well, and came up for their feed with little trouble.

All steers were dipped four times during the progress of the experiment to insure freedom from ticks.

RESULTS OF THE EXPERIMENT.

A summary of this test is shown in Table 1.

TABLE 1.—*Results of summer steer feeding in Alabama, 1912.*

Item.	Lot 1.	Lot 2.	Lot 3.
	Pasture alone.	Pasture and one-half corn chop and one-half cottonseed cake.	Pasture and cottonseed cake.
Number of steers	29	25	36
Days of feeding period	112	106	101
Average daily ration per head:			
Cottonseed cake ... pounds	----------	1.75	3.56
Corn chop ... do	----------	1.75	----------
Cost of feed per 100 pounds gain	$1.71	$5.14	$5.32
Cost per head to feed through summer	$2.00	$7.36	$6.88
Initial cost of steers ... per 100 pounds	$3.87	$3.87	$3.87
Selling price of steers ... do	$4.00	$4.75	$4.75
Average profit per steer	$3.47	$4.69	$4.61
Per cent dressed	48.68	51.91	51.62
Average initial weight ... pounds	646	601	611
Average final (market) weight per head ... do	763	744	740
Average total gain per head ... do	117	143	129
Average daily gain per head ... do	1.04	1.35	1.28

DAILY RATIONS.

When the steers were started on pasture, May 28, each steer of lot 2 received 2.5 pounds of cake and corn mixture daily, and practically the same quantity of cake alone was fed to each steer of lot 3. These moderate allowances were gradually increased until July 13, after which a full feed of 4 pounds of the concentrates was given daily per head until the end of the experiment.

When it is recalled that some of the corn fed to lot 2 was damaged, and that previous experiments had shown that 100 pounds of cottonseed cake usually produce as much gain on steers as 200 pounds of corn, it was to be expected that the steers of lot 3 would make the best gains.

WEIGHTS AND GAINS.

The steers were shipped about 50 miles to market, and the shrinkage was estimated at 3 per cent, thus making the actual daily gain of the steers in all lots somewhat larger than those shown in the table.

Comparison of the relative daily gains shows that lots 2 and 3 made more rapid gains than lot 1, as would be expected. The steers fed a ration of corn chop and cottonseed cake gained faster than those fed cottonseed cake along with the pasture.

The cost of producing 100 pounds increase in live weight in the different lots is much in favor of lot 1. With pasture charged at 50 cents a head for each 28 days, 100 pounds gain in lot 1 cost only $1.71. The average cost of 100 pounds gain in lots 2 and 3 was $5.14 and $5.32, respectively. Thus cheap pasture made the cost of gains lowest for the steers of lot 1, while the more rapid gains of lot 2 were produced 18 cents more cheaply per 100 pounds than those of lot 3, although lot 3 received slightly cheaper feed than lot 2.

SLAUGHTER DATA.

The steers were sold to butchers at Meridian, Miss., about 50 miles from the farm. The dressing percentages show that the steers of lots 2 and 3, which were fed cake and corn, dressed out approximately 3 per cent higher than those getting pasture only, which indicates the higher finish on the cake-and-corn-fed steers. The higher selling price received for these cattle justified the extra cost of the feeds, as will be seen in the financial statement.

TABLE 2.—*Slaughter data.*

Lot No.	Number of steers.	Market weight per head.	Average weight of carcass.	Per cent dressed.
		Pounds.	*Pounds.*	
1	29	763	371	48.65
2	25	744	386	51.38
3	36	740	382	51.62

FINANCIAL STATEMENT.

All the steers cost $3.87 a hundredweight, but those of lot 1, which had pasture alone, sold for 75 cents less per hundredweight than those of the other two lots. The average profits on the steers of lots 1, 2, and 3 were $3.47, $4.69, and $4.61 per head, respectively. While a very small margin was realized on the steers, all returned a profit. The more rapid gains made by the steers of lot 2 account for the slightly greater profit this lot gave over lot 3, while the low rate of gains and the comparatively poor finish of those of lot 1 accounts for the smaller profits they returned. A feeder must not be misled by the high cost of gains alone, as the higher price paid for extra finish on steers often more than compensates for the added cost of feeding relatively high-priced feeds.

RELATIVE VALUE OF MANURE.

Another feature, which does not appear in the results tabulated, is the beneficial effect of the manure on the pasture. The manure from cattle fed cottonseed cake or meal is richer in nitrogen than that from steers fed on pasture only. For example, the steers of lot 3 consumed 13,054 pounds of cottonseed cake containing approximately 800 pounds of nitrogen, practically all of which is returned to the pasture as manure. This nitrogen, valued at 20 cents a pound, is worth $160. If we add the value of the phosphoric acid at 4 cents a pound and the potash at 5 cents a pound, we have a total of about $185.

Thus pastures grazed by steers fed high-protein feeds, such as cottonseed cake and meal or cotton seed, receive the benefit of the fertilizing elements the feeds contain, and consequently become more fertile from year to year.

TABLE 3.—*Financial statement.*

Lot 1, fed pasture alone:	
To 29 steers, 18,745 pounds, at $3.875 a hundredweight	$726.36
To pasture charges, 112 days at 50 cents a head for 28 days	58.00
Total expenditure	784.36
By sale of 29 steers, 22,122 pounds, at $4.00 a hundredweight	884.88
Total profit	100.52
Average profit per head	3.47
Lot 2, fed pasture with one-half cottonseed cake and one-half corn chop:	
To 25 steers, 15,014 pounds, at $3.875 a hundredweight	581.79
To pasture charges, 106 days at 50 cents a head for 28 days	47.50
To 4,662 pounds cottonseed cake at $28.00 a ton	65.27
To 4,662 pounds corn at 85½ cents a bushel	71.20
Total expenditure	765.76
By sale of 25 steers, 18,592 pounds, at $4.75 a hundredweight	883.12
Total profit	117.36
Average profit per head	4.69

Lot 3, fed pasture with cottonseed cake:	
To 36 steers, 22,000 pounds, at $3.87 a hundredweight	$852.50
To pasture charges, 101 days at 50 cents a head for 28 days	64.90
To 13,054 pounds cottonseed cake, at $28.00 a ton	182.76
Total expenditure	1,100.16
By sale of 36 steers, 26,654 pounds, at $4.75 a hundredweight	1,266.06
Total profit	165.90
Average profit per head	4.61

SUMMARY OF ALABAMA EXPERIMENT, 1912.

1. The objects of this test were, (1) to determine whether it is profitable to fatten cattle on summer pasture in Alabama; (2) to compare the results of fattening on pasture alone and on pasture supplemented with cottonseed cake and a combination of cottonseed cake and corn chop; and (3) to compare the relative value, for fattening cattle on pasture, of a combination of cottonseed cake and corn chop with that of cottonseed cake alone.

2. Ninety grade cattle of the beef breeds were used in three lots and fed as follows: Lot 1, 29 head, pasture alone; lot 2, 25 head, pasture and a mixture of one-half cottonseed cake and one-half corn chop; lot 3, 36 head, pasture and cottonseed cake.

3. Besides the pasture the average daily ration per head was 1.75 pounds each of cottonseed cake and corn chop for the steers of lot 2, and 3.56 pounds of cottonseed cake for those of lot 3.

4. The average daily gains per head, using the market weights as the final weights, were 1.04 pounds, 1.35 pounds, and 1.28 pounds for lots 1, 2, and 3, respectively.

5. To produce 100 pounds of gain it cost $1.71 for the steers of lot 1, $5.14 for lot 2, and $5.32 for lot 3.

6. The cattle of lots 2 and 3 dressed out practically the same, 51.91 per cent and 51.62 per cent, respectively. The steers of lot 1, fed on pasture alone, dressed out only 48.68 per cent.

7. The market price received for the steers of lot 1 was 75 cents a hundredweight less than for those of the other lots. The average profits per head were $3.47 for lot 1, $4.69 for lot 2, and $4.61 for lot 3.

II. FATTENING STEERS ON SUMMER PASTURE, ALABAMA, 1913.

OBJECTS AND PLAN OF THE WORK.

The experiment conducted during the summer pasture season of 1913 was essentially a duplicate of the previous year's test except that in the ration of lot 2 corn-and-cob meal was substituted for corn chop. Three lots of steers were carried on pasture from spring until early in the fall, when they were marketed. The 77 head used were divided into three lots and placed on pasture April 8, where they were fed as follows until September 2, when they were sold:

Lot 1, 26 steers, pasture alone.

Lot 2, 25 steers, pasture with one-half cottonseed cake and one-half corn-and-cob meal.

Lot 3, 26 steers, pasture and cottonseed cake.

DESCRIPTION OF CATTLE USED.

The steers used were mostly 3-year-olds, with a few 2-year-olds that had been wintered on the Cobb farm. All were in thrifty condition April 8, 1913, when initial weights were taken. Most of the cattle were grade Aberdeen-Angus, Herefords, and Shorthorns, though a few showed Jersey blood. In general the steers were typical of those raised in Alabama at the time of the experiment.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed cake and meal were of good quality, containing about 38.6 per cent crude protein, and cost $27.50 a ton at the farm. Late in July the supply of cottonseed cake was exhausted and cottonseed meal was used to finish the steers.

The corn, which was fed as corn-and-cob meal, was sound and good. The entire ears and the husks were ground together and charged against the steers at 70 cents a bushel.

CONDITION OF PASTURES.

The same pastures were used as in the 1912 experiment, but all of them furnished better grazing. The pasture of lot 1 had more sweet clovers. The only water in the pasture of lot 3 was that in ditches and pools; lots 1 and 2 had both well water and ditch water. Except for a short, dry period early in May, rains were quite frequent, and the steers had an abundance of grass throughout the summer. Pasture was charged at 50 cents a head for each 28-day period.

METHOD OF FEEDING AND HANDLING.

Each day, about sundown, the steers in lots 2 and 3 were fed in troughs in the open pasture. Initial and final weights of every animal were taken and each lot was weighed at the end of each 28-day period. All were dipped in an arsenical dip five times during the experiment, to keep them free from ticks. Salt was provided once a week.

RESULTS OF THE EXPERIMENT.

Table 4 shows the chief features of the experiment.

TABLE 4.—*Results of summer steer feeding in Alabama, 1913.*

Item.	Lot 1.	Lot 2.	Lot 3.
	Pasture alone.	Pasture and one-half corn-and-cob meal and one-half cottonseed cake.	Pasture and cottonseed cake.
Number of steers	26	25	26
Days of feeding period	147	147	147
Average daily ration per head:			
Cottonseed cake ... pounds	.....	1.79	3.70
Corn-and-cob meal ... do	.....	1.76	.....
Cost of pasture and feed for 100 pounds gain	$1.09	$3.51	$3.27
Cost per head to feed through summer	$2.62	$9.71	$10.12
Initial cost of steers per 100 pounds	$5.25	$5.25	$5.25
Selling price of steers per 100 pounds	$5.00	$6.00	$6.00
Average profit per head	$6.60	$8.27	$11.23
Average initial weight per head ... pounds	610	588	593
Average final (farm) weight per head ... do	850	840	902
Average total gain per head ... do	240	252	309
Average daily gain per head ... do	1.63	1.71	2.10

DAILY RATION.

The steers had been fed cake lightly for about 5 weeks before the test. Lots 2 and 3 were given, therefore, 3 pounds of concentrates per head at the beginning, and the quantity was gradually increased until on May 10 the steers of lot 2 were eating daily 2 pounds of cottonseed cake and 2 pounds of corn-and-cob meal per head, and those of lot 3 were each eating 4 pounds of cottonseed cake daily. These quantities were fed daily until the end of the experiment, September 2.

COMPARATIVE GAINS.

Lot 1 made an average daily gain of 1.63 pounds a head, a very satisfactory result for such steers.

Lot 2 gained 1.71 pounds per head daily. While this gain was greater than that of the steers in lot 1, it is less than would be expected from the feeding method used.

Lot 3, having cottonseed cake in addition to pasture, made very good gains for that class of steers. From the standpoint of produc-

ing rapid gains, the results indicate that cottonseed cake alone as a supplement to pasture is greatly superior to the half-and-half mixture of cottonseed cake and corn-and-cob meal fed to the steers in lot 2.

COST OF GAINS.

The cost of gains was lower than in the previous year, attributable to the more rapid gains made in 1913 and the slightly cheaper feeds.

The pasture, charged at 50 cents a head for each 28-day period, cost $2.62 per steer throughout the 147-day period. This, of course, was the entire feed charge against the steers of lot 1. It cost $9.71 a head to pasture and feed the steers of lot 2, and $10.12 a head for those of lot 3. The rapid gains of the steers in lot 3, however, made the cost of gains lower than those of lot 2, although the latter were getting cheaper feed.

The steers were sold by farm weights less 3 per cent shrinkage, and were shipped to Meridian, Miss., for slaughter. All were not shipped at the close of the experiment, so that the slaughter records were not obtained.

FINANCIAL STATEMENT.

The value of the steers at the beginning of the experiment was $5.25 a hundredweight. Those of lot 1, which had pasture only, sold for $5 a hundredweight in the fall, but even in the face of such a handicap made a profit of $6.60 a head. This remarkable showing is due entirely to the good gains which the steers made on cheap pastures. The steers in the other two lots were fed the supplemental ration to advantage, since they sold for $6 a hundredweight, which was $1 more than the lot 1 price. The relative profits indicate that it pays to feed cottonseed cake to steers on pasture, but the substitution of corn-and-cob meal, which costs but a few dollars a ton less than cottonseed cake, for one-half the cake, is not so profitable as feeding cake alone.

The value of manure from the steers of lots 2 and 3 also must be considered.

The important results agree with those obtained the previous year and again high costs of gain, due to the additional feed of cake and corn, were more than paid for by the higher selling price of the better-finished steers in lots 2 and 3.

TABLE 5.—*Financial statement.*

Lot 1, fed pasture alone:	
To 26 steers, 15,854 pounds, at $5.25 a hundredweight	$832.33
To pasture charges at 50 cents a head for 28 days	68.25
Total expenditure	900.58
By sale of 26 steers, 21,447 pounds, at $5 a hundredweight	1,072.35
Total profit	171.77
Average profit per steer	6.60

Lot 2, fed pasture and half cottonseed cake and half corn-and-cob meal:	
To 25 steers, 14,705 pounds, at $5.25 a hundredweight	$772.01
To 6,611 pounds cottonseed cake at $27.50 a ton	90.90
To 8,637 pounds ear corn at 70 cents a bushel	86.37
To pasture charges at 50 cents a head for 28 days	65.63
Total expenditure	1,014.91
By sale of 25 steers, 20,361 pounds, at $6 a hundredweight	1,221.66
Total profit	206.75
Average profit per head	8.27
Lot 3, fed pasture and cottonseed cake:	
To 26 steers, 15,418 pounds, at $5.25 a hundredweight	809.44
To 14,171 pounds cottonseed cake at $27.50 a ton	194.85
To pasture charges at 50 cents a head for 28 days	68.25
Total expenditure	1,072.54
By sale of 26 steers, 22,741 pounds, at $6 a hundredweight	1,364.46
Total profit	291.92
Average profit per head	11.23

SUMMARY OF ALABAMA EXPERIMENT, 1913.

1. The objects and general plan for the test were similar to those for the previous year. The 3 lots were on feed 147 days.

2. The steers used were 2 and 3 year old grades, 77 head in all, carrying a large percentage of the blood of beef breeds. They were divided and fed as follows: Lot 1, 26 head, pasture only; lot 2, 25 head, pasture and one-half cottonseed cake and one-half corn-and-cob meal; lot 3, 26 head, pasture and cottonseed cake.

3. The average daily ration of concentrates was 3.55 pounds of the half-and-half mixture of cottonseed cake and corn-and-cob meal per head for the steers of lot 2, and 3.70 pounds of cottonseed cake for those of lot 3.

4. The average daily gains were 1.63 pounds a head for the steers of lot 1, 1.71 pounds for lot 2, and 2.10 pounds for lot 3.

5. The cost of feed and pasture to produce 100 pounds of gain was $1.09, $3.51, and $3.27 for lots 1, 2, and 3, respectively.

6. The finished cattle of lots 2 and 3, which were fed supplements in addition to the pasture, sold for $1 a hundredweight more than those of lot 1.

7. The cake-fed steers returned a profit of $11.23 a head, the cake-and-corn-fed steers $8.27 a head, and those pastured without other feed made a profit of $6.60 a head.

III. FATTENING STEERS ON SUMMER PASTURE, MISSISSIPPI, 1915.

The cooperative experiments in fattening cattle on pastures in the South were discontinued in Alabama after the test of 1913 and transferred to Mississippi, where the work was continued in cooperation with the Mississippi Experiment Station. The present experiment was conducted on the farm of Ben Walker at Abbott, Clay County, Miss., who furnished the cattle, feeds, and pastures.

The soil and pasture grasses are very similar to those of Sumter County, Ala., where the previous work was conducted. Clay County, Miss., is in the so-called black-prairie section, the soils of which carry a good supply of lime, and produce alfalfa, clovers, grasses, and forage crops in abundance. The land, however, is less rolling than that in Sumter County, Ala. N. F. Hansen was employed by the bureau to take personal charge of the cattle in the experiments and to keep records of the work.

OBJECTS AND PLAN OF THE WORK.

The objects of this test were to obtain additional information and data concerning the fattening of steers on summer pasture in the South. The same general plan was followed as in the Alabama experiments. The steers were placed on pasture in the spring and fattened for early fall market. Owing to the high price of corn at Abbott in the spring of 1915 only two lots were used.

Forty steers were divided into 2 lots of 20 each and fed as follows: Lot 1, 20 steers, pasture alone; lot 2, 20 steers, pasture and cottonseed cake.

DESCRIPTION OF CATTLE USED.

The 40 steers in this experiment were ordinary natives of mixed and inferior breeding. Jersey blood predominated in all but a few, which showed evidences of Angus and Shorthorn blood. They had been wintered on cottonseed meal, cottonseed hulls, and corn silage, and were in good condition when the experiment began, averaging 678 pounds.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed cake which was fed to the steers of lot 2 was of high quality, analyzing 43 per cent crude protein, and cost $29.60 a ton delivered at the farm.

The pastures were practically equal in size and in the area of grazing furnished for each lot. The grasses making up these pas-

tures are much the same as those found in the Alabama pastures previously described. Lespedeza, Bermuda grass, and crab grass are the most important ones.

Owing to a dry period early in the spring of 1915 the pastures were not ready for use until late in May, and in midsummer a drought of two months' duration almost ruined the pastures for the season. Rains during the latter part of August also injured them somewhat. Owing to these unsatisfactory conditions good gains on the cattle could hardly be expected. The pasture was charged at the rate of 50 cents a head for each period of 28 days, as in the Alabama tests.

METHOD OF FEEDING AND HANDLING THE CATTLE.

The cottonseed cake was fed each evening about sundown in troughs placed in the pasture. Pools in the open pastures furnished the only source of water supply for the steers, and became very low and foul during the extended dry period. Salt was provided each week.

Individual weights of all the steers were taken at the beginning and at the end of the experiment, and each lot was weighed every 28 days. As the cattle were free from ticks, no dipping was done.

RESULTS OF THE EXPERIMENT.

Table 6 gives in brief the general features and results of the experiment.

TABLE 6.—*Results of summer steer feeding in Mississippi, 1915.*

Item.	Lot 1. Pasture alone.	Lot 2. Pasture and cottonseed cake.
Number of steers	20	20
Days of feeding period	107	107
Average daily ration per head:		
Cottonseed cake ... pounds	.....	3.65
Cost of feed and pasture per 100 pounds gain	$1.06	$3.44
Cost per head to feed through summer	$1.91	$7.37
Initial cost of steers per 100 pounds	$5.00	$5.00
Selling price of steers per 100 pounds	$5.75	$6.35
Average profit per steer	$7.19	$9.61
Per cent dressed	(1)	50.8
Average initial weight per head ... pounds	678	678
Average final weight per head ... do	858	892
Average total gain per head ... do	180	214
Average daily gain per head ... do	1.68	2.00

[1] Lot 1 sold as stockers.

DAILY RATIONS.

The average daily ration of cottonseed cake for the steers of lot 2 was 3.65 pounds each. They were given 2 pounds a head daily at the beginning, which was gradually increased during the first month

to 4 pounds. This allowance was continued until the end of the experiment.

WEIGHTS AND GAINS.

The steers were equally divided so that the average weight in both lots was 678 pounds. The average total gain was 180 pounds for the steers of lot 1 and 214 pounds for those of lot 2. The average daily gain was 1.68 pounds for the steers of lot 1 and 2 pounds for those of lot 2. Considering the kind of steers and the dry season, these gains were very good. As would be expected, the cake-fed steers made the better gains, each steer putting on an average of 34 pounds more than those getting pasture alone.

COST OF GAINS.

The gains for lot 2 cost more than three times as much as those for lot 1. Each 100 pounds of gain for the steers of lot 1 cost only $1.06, while the same gains for lot 2 cost $3.44, but on account of the higher selling price the profit on lot 2 was greater. These figures are about the same as for the summer test of 1913 in Alabama.

SLAUGHTER DATA.

The steers were sold on the St. Louis market. Those of lot 1 were sold as stockers, and data on shrinkage were not obtained. For lot 2 the average final farm weight was 892 pounds, the average market weight was 847 pounds, and the net shrinkage in transit was 45 pounds a head. The steers dressed out 50.8 per cent of the market weights, which was satisfactory for that class of steers.

FINANCIAL STATEMENT.

The financial statement shows results similar to those of the steers fed in Alabama in 1912 and 1913. The steers fed cake on pasture brought the higher price again and made the greater profit. The initial cost per hundred pounds was $5 for all the steers, those of lot 1 sold as stockers for $5.75 a hundred pounds, and those of lot 2 brought $6.35 as finished beeves. The average profit for lot 1 was $7.19 a head, and $9.61 for lot 2, which was satisfactory for both lots.

TABLE 7.—*Financial statement.*

Lot 1, fed pasture alone:	
To 20 steers, 13,557 pounds, at $5 a hundredweight	$677.85
To pasture, 107 days at 50 cents per steer per 28 days	38.20
To freight, commission, yardage, etc	57.92
Total cost	773.97
By sale of 20 steers, 15,960 pounds, at $5.75 a hundredweight	917.70
Total profit	143.73
Average profit per steer	7.19

Lot 2, fed pasture and cottonseed cake:	
To 20 steers, 13,551 pounds, at $5 a hundredweight	$677.55
To pasture, 107 days at 50 cents per steer per 28 days	38.20
To cottonseed cake, 7,380 pounds, at $29.60 a ton	109.22
To freight, commission, yardage, etc	57.92
Total cost	882.89
By sale of 20 steers, 16,930 pounds, at $6.35 a hundredweight	1,075.05
Total profit	192.16
Average profit per steer	9.61

As in the work of 1912 and 1913, the cost of gains was much higher for the steers which received cake in addition to their pasture, but the higher finish which the cake-fed steers took on, and the consequent higher selling price, more than compensated for the increased cost of feeding the cake, as the profits show. The increased value of the manure from the cake-fed steers also should be taken into consideration.

SUMMARY OF THE EXPERIMENT.

1. The objects of this test were to continue the study of fattening mature steers on pasture in the South, including the use of cottonseed cake with pasture.

2. The cattle used were ordinary native cattle of mixed breeding. There were 40 head, which were divided into 2 lots equal in quality and weight and fed as follows: Lot 1, 20 head, pasture alone; lot 2, 20 head, pasture and cottonseed cake. The steers were put on pasture May 20 and fed until September 5, or 107 days in all.

3. The steers of lot 2 ate an average daily feed of 3.65 pounds of cottonseed cake.

4. Lot 1 made an average daily gain of 1.68 pounds per head; lot 2 gained 2 pounds per head daily.

5. To produce 100 pounds of gain, it cost $1.06 for the steers of lot 1, and $3.44 for those of lot 2.

6. The steers of lot 1, which had no other feed than pasture, were not finished, and were sold as stockers for $5.75 a hundredweight, while those of lot 2, which were fed cottonseed cake with the pasture, sold for $6.35 a hundredweight for the block.

7. Lot 1 made a profit of $7.19 a head, compared with $9.61 a head for lot 2.

IV. FATTENING STEERS ON SUMMER PASTURE, MISSISSIPPI, 1916.

The series of experiements in fattening steers on summer pasture was continued in the summer of 1916 in cooperation with the Mississippi Experiment Station on the Canton Stock Farm, near Canton, Madison County, Miss. The stock, feed, pastures, and equipment were furnished by the farm. The bureau placed S. S. Jerdan on the farm to supervise the feeding of the cattle and keep records of the test.

OBJECTS AND PLAN OF THE EXPERIMENT.

The experiment had for its chief object a further study of the fattening of steers on summer pasture, emphasizing especially the comparison of pasture alone and pasture supplemented with cottonseed cake. The test was planned along the same lines as the previous ones.

Corn was not to be had at reasonable prices, so only two lots of 30 steers each were used, one lot getting pasture alone, the other cottonseed cake in addition to the pasture.

CATTLE USED.

The stock used in this test were inferior mature steers of nondescript breeding, weighing from 550 pounds to 1,000 pounds each when the experiment began. Evidences of Jersey breeding were most prominent, while a few showed marks of Shorthorn, Hereford, Aberdeen-Angus, Red Polled, and Devon breeding. As a whole they were typical scrub steers of the South, and very few were good feeders. All but 15, which were raised on the farm, had been bought in Madison County early in May. They were divided into 2 lots of 30 each, as equally as possible in regard to size, condition, and quality. Madison County is in tick-free territory, and as no ticks were on the animals dipping was unnecessary.

CHARACTER AND PRICES OF FEEDS USED.

The cottonseed cake was of good quality, cracked to nut size, and analysis showed about 39 per cent crude protein. The steers ate it with relish. It cost $32 a ton in Canton, the cost of hauling it to the farm not being added.

The pastures were quite similar to those described in the work in Sumter County, Ala., and at Abbott, Miss. This region is in what is called the "brown-loam" classification, and the soil is very fertile, producing a great variety of grasses and clovers. The principal plants which furnished grazing were lespedeza, Paspalum, Bermuda

grass, white clover, and some crab grass. No stock had been on the pastures before the experiment began, so that an abundance of grass and clover was available for the cattle throughout the experiment.

Heavy rains sometimes caused water to stand on parts of both pastures, and the grass was considered too "washy" to produce the best gains on the cattle. Parts of the pastures were clipped with a mower late in July, causing some improvement.

The two lots of steers were interchanged from one pasture to the other, so that discrepancies due to a difference in pastures might be avoided. Pasture was charged at the rate of 50 cents a head for a 28-day period.

METHOD OF FEEDING AND HANDLING THE CATTLE.

The steers of lot 2 were fed their cake in troughs in the pasture about sundown each day. They came up well for their feed, and relished it. Water was obtained from ditches and pools in the pastures. Individual weights of all steers were taken at the beginning and at the close of the test, and each lot was weighed at the end of each 28-day period while the experiment was in progress.

RESULTS OF THE EXPERIMENT.

The main features and results of the test are shown in Table 8, in which the two lots are compared with respect to rate of gains, cost of gains, profits, etc.

TABLE 8.—*Results of summer steer feeding in Mississippi, 1916.*

Item.	Lot 1. Pasture alone.	Lot 2. Pasture and cotton seed cake.
Number of steers	30	30
Days of feeding period	134	134
Average daily ration per head:		
Cottonseed cake ... pounds		4.32
Cost of pasture and feed for 100 pounds gain	$1.12	$4.54
Cost per head to feed through summer	$2.39	$11.67
Initial cost of steers per 100 pounds	$5.50	$5.50
Selling price of steers per 100 pounds	$5.85	$6.10
Average profit per head	$5.88	[1] $0.05
Average initial weight per head ... pounds	662	664
Average final weight per head ... do	876	921
Average total gain per head ... do	214	257
Average daily gain per head ... do	1.60	1.92

[1] A loss.

DAILY RATIONS.

Lot 1 had only pasture. Cottonseed cake was fed to lot 2 at the rate of 2 pounds a head daily for the first few days. This was increased gradually during the first 3 periods, until on August 1 the

average daily allowance per head was 5 pounds, which quantity was fed until the steers were marketed. The average daily ration of cake for the 134 days was 4.32 pounds a head.

WEIGHTS AND GAINS.

The average weight of the steers of lot 1 was 662 pounds when the experiment began, and they gained a total of 214 pounds a head, which was a daily gain of 1.6 pounds. For the grade of steers used these gains were fairly satisfactory.

The average initial weight of the steers of lot 2 was 664 pounds a head, and the final weight 921 pounds, showing a total gain of 257 pounds a head, equal to an average daily gain of 1.92 pounds for the period of 134 days. As would be expected, they gained more rapidly than those of lot 1, but better steers would have made larger gains.

COST OF GAINS.

The cost of gains for the steers getting pasture alone was low, as in previous tests, but the gains of those fed cottonseed cake on pasture cost more in this experiment than in 1913 and 1915, due principally to the higher cost and more liberal use of the cake.

The cost of feed per head through the summer was $2.39 for lot 1 and $11.67 for lot 2.

SLAUGHTER DATA.

The steers were taken off the experiment on September 28, driven to Canton on September 29, shipped to the St. Louis market, and slaughtered. After the steers had taken their "fill" at the market and were weighed, it was found that those of lot 1 had lost an average of 57 pounds, while those of lot 2 had lost 79 pounds. This wide variation in shrinkage between the 2 lots can not be accounted for. The conclusion that cake-fed steers shrink more in transit than grass-fed cattle is not supported by the results of many other shipments of steers.

The per cent of dressing was 51.17 for the steers of lot 1 and 54.21 for those of lot 2, which indicates the superior finish of the cake-fed steers. The latter were much better covered with fat than those of lot 1.

TABLE 9.—*Shipping and slaughter data.*

Item.	Lot 1.	Lot 2.
Number of steers	30	30
Average final farm weight per head ... pounds	876	921
Average market weight per head ... do	819	842
Average shrinkage in transit per head ... do	57	79
Average weight of carcass ... do	419	457
Per cent dressed	51.17	54.21

FINANCIAL STATEMENT.

The following statement shows the cost of steers, cost of feeds and marketing, and the receipts at the markets for each of the two lots. It is seen that the steers of lot 1 returned a net profit of $5.88 a head, while those of lot 2 showed a loss of 5 cents a head.

Of the four years' work this lot of steers which had cake with pasture is the only one which did not make a profit. Several things are responsible for this fact. The steers were sold on a small margin of 60 cents a hundred pounds, which is low for steers fed concentrates; the higher cost of the cottonseed cake also made the feeding more expensive than in former years. The steers used in the test were scrubs of very common breeding and poor quality, which accounts in a degree for the smaller margin of profit obtained. The steers used in previous tests were grade beef steers somewhat above the average of the State in quality and breeding. This indicates the desirability of having well-bred steers of high quality when expensive feeds are to be used. In addition to the disadvantages mentioned, the steers of lot 2 suffered a heavy shrinkage in transit to market in comparison with those of lot 1, which materially reduced the receipts.

Some credit also should be given to the steers of lot 2 for the added fertilizing value of their manure, because of the cottonseed cake which they had. Finally, it should be noted that a greater margin than is shown for these two lots of steers can usually be realized on cattle bought in the spring and marketed early in the fall, as these cattle were.

TABLE 10.—*Financial statement.*

Lot 1, fed pasture alone:	
To 30 steers, 19,865 pounds, at $5.50 a hundredweight	$1,092.58
To pasture, 134 days at 50 cents per 28 days	71.78
To freight charges to market $70, commission $15	85.00
To feed in transit and in yards $6, yardage $5.85, insurance 22 cents	12.07
Total expenditure	1,261.43
By sale of 30 steers, 24,580 pounds, at $5.85 a hundredweight	1,437.93
Total profit	176.50
Average profit per steer	5.88
Lot 2, fed pasture and cottonseed cake:	
To 30 steers, 19,922 pounds, at $5.50 a hundredweight	1,095.71
To pasture, 134 days at 50 cents per head per 28 days	71.78
To 17,400 pounds cottonseed cake at $32 a ton	278.40
To freight charges to market $70, commission $15	85.00
To feed in transit and in yards $6, yardage $5.85, insurance 23 cents	12.08
Total expenditure	1,542.97
By sale of 30 steers, 25,270 pounds, at $6.10 a hundredweight	1,541.47
Total loss	1.50
Average loss per steer	.05

SUMMARY OF THE EXPERIMENT.

1. The objects sought and the general plan pursued in this experiment were identical with those reported in the first three parts of

this bulletin. Two lots of 30 steers each were used, one lot having pasture alone and the other cottonseed cake with the pasture.

2. The cattle were inferior stock of mixed breeding, Jersey blood predominating.

3. The average daily ration of the cake-fed steers was 4.32 pounds a head.

4. The average daily gains per head were 1.6 pounds for the steers of lot 1, and 1.92 pounds for those of lot 2.

5. The cost of feed and pasture to produce 100 pounds of gain was $1.12 for the steers on pasture alone and $4.54 for those fed cake with the pasture.

6. The shrinkage in transit to market was 57 pounds and 79 pounds, respectively, per head for the steers of lots 1 and 2. No explanation can be made for so great a difference in shrinkage.

7. The dressing per cent for lot 1 was 51.17 and 54.21 per cent for lot 2, indicating superior finish on the cake-fed steers.

8. The scrub steers of this test failed to realize a profit when fed a high-priced supplementary feed, whereas the grade beef steers used in previous tests invariably returned good profits.

V. SUMMARY OF THE FOUR YEARS' SUMMER FATTENING EXPERIMENTS.

The more important data of the four years' summer fattening work are shown in condensed form by Table 11. This permits a direct comparison to be made of the results from the different methods used.

Comparing the averages of the three methods of fattening the steers, it will be noted that there was little difference in the average length of feeding and pasture periods. The average daily gains per head, which may be considered the most valuable standard in judging the efficiency of rations, were 1.49 pounds for the steers getting pasture only, 1.83 pounds for the steers getting cottonseed cake with pasture, and 1.53 pounds for those whose pastures were supplemented with the mixture of cake and corn chop.

The initial cost of the steers per 100 pounds of the three groups was the same for any one year, but in each case the steers of group I (pasture alone) sold for a lower price. The margins realized between the buying and selling prices of the cattle were always in favor of those which were fed supplements with their pastures. The margins averaged 24½ cents a hundredweight for the steers of group I, 90 cents for group II, and 81½ cents for group III.

While the data on the dressing per cent are not complete, inspection of the results given will show that the steers which were fed cottonseed cake or a mixture of cake and corn with pasture dressed out higher than the cattle which had pasture alone.

The steers of group I, which had pasture only, returned an average profit of $5.78 a head, against $6.23 for the cake-fed steers, and $6.48 for those on cake and corn. The average profit made on the cake-fed steers is adversely affected by the small loss on the lot fed in 1916. This poor result was caused by a combination of unfortunate conditions and the use of scrub steers.

TABLE 11.—*Summary of four years' summer fattening work.*

Group, ration, and year.	Number of steers.	Days fed.	Average total gain per head.	Average daily gain per head.	Cost of feed per 100 pounds gain.	Cost of cattle per 100 pounds.	Selling price per 100 pounds.	Margin per 100 pounds.	Dressing per cent.	Average profit per head.
I. Pasture alone:			*Lbs.*	*Lbs.*					*Per ct.*	
1912	29	112	117	1.04	$1.71	$3.87	$4.00	$0.13	48.68	$3.47
1913	26	147	240	1.63	1.09	5.25	5.00	[1] .25	.....	6.60
1915	20	107	180	1.68	1.06	5.00	5.75	.75	.....	7.19
1916	30	134	214	1.60	1.12	5.50	5.85	.35	51.17	5.88
Average	.....	125	188	1.49	1.25	4.90	5.15	.245	49.92	5.78

[1] A loss.

TABLE 11.—*Summary of four years' summer fattening work*—Continued.

Group, ration, and year.	Number of steers.	Days fed.	Average total gain per head.	Average daily gain per head.	Cost of feed per 100 pounds gain.	Cost of cattle per 100 pounds.	Selling price per 100 pounds.	Margin per 100 pounds.	Dressing per cent.	Average profit per head.
II. Pasture and cottonseed cake:			*Lbs.*	*Lbs.*					*Per ct.*	
1912	36	101	129	1.28	$5.32	$3.87	$4.75	$0.88	51.62	$4.61
1913	26	147	309	2.10	3.27	5.25	6.00	.75	.....	11.23
1915	20	107	214	2.00	3.44	5.00	6.35	1.35	50.80	9.61
1916	30	134	257	1.92	4.54	5.50	6.10	.60	54.21	[1] .05
Average	.....	122	227	1.83	4.14	4.90	5 80	90	52.21	6 23
III. Pasture with half cottonseed cake and one-half corn chop: [2]										
1912	25	106	143	1 35	5 14	3 87	4.75	.88	51.91	4.69
1913	25	147	252	1.71	3.51	5.25	6.00	.75	.....	8.27
Average	.....	126	198	1.53	4.32	4.56	5.37	.815	51.91	6.48

[1] A loss.
[2] Corn-and-cob meal fed in 1913.

The figures shown in Table 11 afford material for profitable study by farmers and feeders. It is seen that the steers in group I made gains very cheaply, but the total gains were not large and the steers did not take on a high finish. Their unfinished condition is reflected in the small margin on which they were sold and the low dressing percentages. Thus the profits they returned were smaller than for the steers of the other two groups.

The steers under group II made more rapid gains than the grass-fed cattle, but their gains cost more. However, they were better finished, as shown by the dressing percentages, and sold on the market for a higher price per hundredweight, which paid for the relatively expensive gains and returned a greater profit per head than was realized on the cattle in group I.

Since only two lots of steers were fed under group III, and because corn chop was fed to one and corn-and-cob meal to the other, the average results do not have the same weight as those of the first two groups. As they stand, the data show that the substitution of corn pound for pound for one-half of the cottonseed-cake allowance lowered slightly the rate of gains and increased the cost of gains. The steers of this group, however, gained more rapidly, finished in better condition, and brought higher prices and a larger profit per head than those of group I.

While the average profit per head for group III is greater than for the other two groups, a comparison of the profits of group II and III for 1912 and 1913 shows that the steers of group II returned the larger net profit per head for those two years.

CONCLUSIONS.

The methods of handling and feeding cattle are greatly affected by the constant variations in the prices of different feeds, by seasonal conditions, and by the changes in the live-stock markets. The following conclusions may be drawn from the experimental work reported in this bulletin:

1. Feeding cottonseed cake to steers as a supplement to summer pasture in the South increases materially the rate of gains made by steers, causes them to finish more quickly, and to take on a higher degree of finish.

2. Because of their better finished condition cake-fed steers bring higher prices on the markets than grass cattle. The margin or "spread" between buying and selling prices of steers fattened on pasture is nearly always increased by supplementing the pasture with cottonseed cake, or cake and corn.

3. Steers of inferior quality may return more profit by grazing alone than by grazing with the addition of supplementary feeds, especially when they are on good pastures that are cheap.

4. The cost of gains of steers on pasture is greatly increased by feeding cottonseed cake, but the better market price received for cake-fed cattle usually pays for the added cost of feeding the cake and returns a greater average profit than is realized on grass-fed cattle.

5. The substitution of corn chop for one-half the quantity of cottonseed cake for steers on pasture produces gains and finish comparable to those made by cake alone, but unless corn is available at a lower cost than the cake its use for this purpose is not recommended.

6. A half-and-half mixture of cottonseed cake and corn-and-cob meal for steers on grass is less efficient for producing gains than cottonseed cake alone or corn and cake. When corn is cheap its use shelled or as corn chop with cottonseed cake is preferable to corn-and-cob meal.

7. Pasture lands grazed by steers that are fed cottonseed meal or cake receive the benefit of large quantities of fertilizing elements through the manure of the cattle. The landowner should consider this feature when fattening cattle on pasture.

8. One of the distinct advantages in supplementing pastures with concentrates is the fact that steers so handled are finished more quickly and can be marketed earlier than steers getting grass alone. Thus the cattle can be sold before the rush of grass-fed cattle gluts the market and depresses prices. Moreover, when cattle are marketed early the pastures have time to recuperate and furnish good grazing for other stock during the fall.

9. Scrub steers do not respond readily to the use of good feeds, and even when well finished do not command satisfactory prices in competition with well-bred cattle similarly finished. On the other hand, good grade or pure-bred beef cattle make better use of their feeds, finish more rapidly, and always bring more on the market than scrub cattle of the same weight. The better the quality of the steers the safer it is to feed them high-priced feeds.

10. For a farmer who has roughages such as silage, hay, straw, stover, cottonseed hulls, or stalk feeds, and contemplates fattening steers on summer pasture, it is usually better to purchase the steers in the fall, and winter them on the roughages and a little cottonseed meal than it is to purchase them in the spring for fattening during the grazing season.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 778

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

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THE ROSE MIDGE.

By E. R. Sasscer, *Collaborator*, and A. D. Borden, *Scientific Assistant, Tropical and Subtropical Fruit Insect Investigations.*

CONTENTS.

INTRODUCTION.

The rose midge, *Dasyneura rhodophaga* (Coq.), an insect related to the Hessian fly, is often the cause of considerable injury to roses grown under glass. In 1912 Davis (3)[1] estimated that the loss due to this pest in two Chicago greenhouses would approximate $10,000 annually. Subsequently this insect was reported by various entomologists as being especially injurious to the flower and leaf buds of the rose, distorting their growth and eventually causing them to turn brown and die.

In the fall of 1916 an infestation was located at Colgate, Md., which, according to the owner, caused an annual loss of from $4,000 to $6,000. Although the house was generally infested, the infestation was limited to the following varieties of roses: Radiance (pink), Hadley (red), Russell (pink), and Killarney (white). The Hadley and Radiance varieties were most severely infested, scarcely a leaf or flower bud escaping attack.

This infestation offered an excellent opportunity for determining a satisfactory means of controlling this pest in a commercial greenhouse, and, in collaboration with Prof. E. N. Cory, entomologist of the Maryland Agricultural Experiment Station, the investigation was begun in October, 1916. Results of these experiments are given on pages 6 and 7.

[1] Figures in parentheses refer to "Literature cited," p. 8.

HISTORY AND DISTRIBUTION.

This rose pest, together with a closely related species, *Diplosis rosivora* Coq., was first collected in New Jersey, in 1886 (1). It was collected later in New Jersey in 1889, in New York in 1890, in the District of Columbia in 1891, 1894, and 1896, in Massachusetts in 1894, and in Chicago, Ill., in 1897 (2, p. 15). In 1903 specimens were sent to the Bureau of Entomology from Cleveland, Ohio, infesting the Meteor variety, with the report that as many as 35 larvæ had been taken from a single bud. Apparently the same insect was received from Cincinnati, Ohio, in 1905, where it was seriously damaging the buds and tips of the La France and Duchess of Albany. Notwithstanding the fact that in the houses containing both varieties the heat was turned off throughout the entire winter, the correspondent reported that the hibernating midge was not killed.

In 1911 a heavy infestation of the variety My Maryland was reported from Rhode Island, and in 1915 Hewitt (5) recorded the occurrence of this midge in a garden at London, Ont., infesting shoots of the variety Mrs. J. Laing. In 1916 Gibson (8) reported it from the same locality and also in greenhouses at Toronto, Ont. Snodgrass (7) includes the rose midge among the important insect pests of Indiana, and Crosby and Leonard (6) state that it attacks roses grown in the open in New York.

Although the rose midge has been reported frequently from several States, it does not necessarily follow that these infestations are still in existence, since some of the varieties subject to infestation have been given up for more resistant and profitable varieties, and in others the insects may have been exterminated by the use of insecticides. Rose houses in the District of Columbia were repeatedly inspected during the past two years, and no infestations were located.

DESCRIPTION.[1]

EGG.

FIG. 1, A.

Egg elongate ovoid, yellowish, about 0.32 mm. long and 0.075 mm. in width.

LARVA.

FIG. 1, C.

Full-grown larva about 1.8 mm. in length, 0.45 mm. in width, reddish in color, obtuse and tuberculated on posterior segment, tubercles bearing minute apical spines, lateral margins distinctly compressed, attenuated anteriorly, breast-bone distinct, with distinct black spot on upper side immediately in front of breast-bone.

PUPA.

FIG. 1, E.

Length of pupa 1.6 mm., width 0.53 mm.; color varying from reddish to reddish yellow, eyes black at time of emerging from cocoon, legs and antennæ approaching black with head and prothorax dusky; all segments except first

[1] The descriptions of the egg, larva, and pupa are compiled from Webster (2, p. 21–23); that of the adults is copied verbatim from Felt (4).

bearing a transverse spinulose ridge on dorsal surface, ventral surface without these ridges; bases of antennæ produced with usual pair of bristles immediately posterior to them and with two large respiratory tubes protruding through cocoon.

ADULT.

Male [Fig. 1, F]. Length 1 mm. Antennæ short, 9 subsessile segments, the fifth with a length only a little greater than its diameter, the last segment greatly produced, with a length about four times its diameter. Palpi; the first

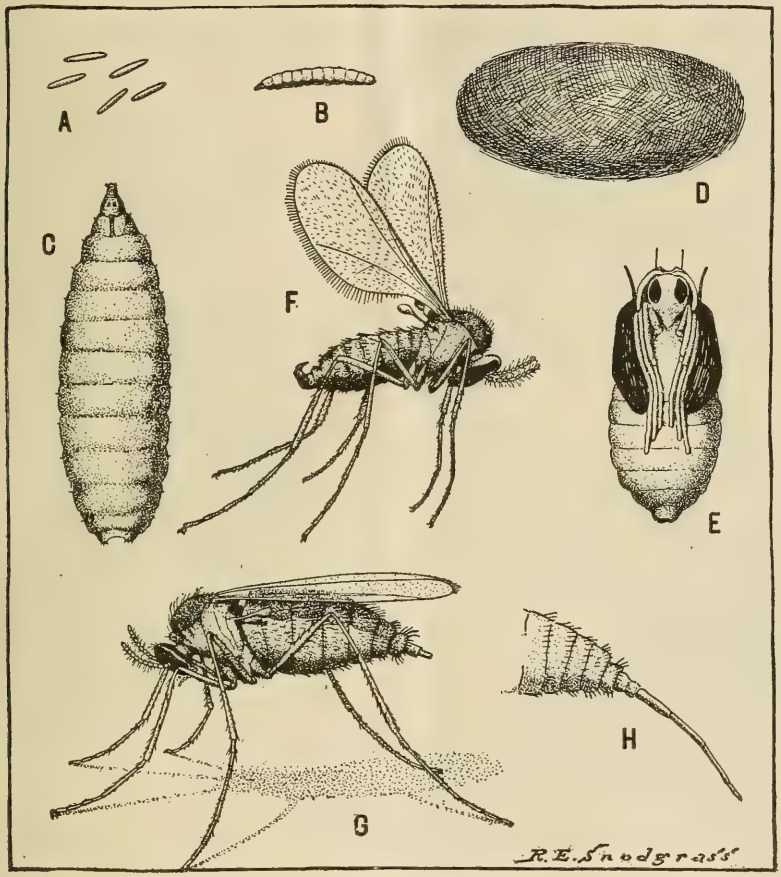

FIG. 1.—The rose midge (*Dasyneura rhodophaga*), enlarged about 27 diameters: *A*, eggs; *B*, young larva; *C*, full-grown larva; *D*, cocoon; *E*, pupa; *F*, adult male; *G*, adult female; *H*, female ovipositor. (9th Ann. Rept. State Ent. Ind.)

segment short, the second broadly oval, the third one-half longer, dilated, the fourth as long as the third, slender. Head and thorax brown, the abdomen, in alcoholic specimens, yellowish. Wings hyaline, costa dark brown, third vein curving forward. Claws long, slender, the pulvilli a little shorter than the claws. Genitalia; basal clasp segment slender; terminal clasp segment long, slightly swollen basally; dorsal plate broad, deeply and narrowly incised, ventral plate long, broadly and roundly emarginate. Harpes long, subtruncate and irregularly tuberculate.

Female [Fig. 1, G]. Length 1 to 1.25 mm. Antennæ short; 9 subsessile segments, the fifth with a length nearly twice its diameter, the terminal segment

greatly produced, with a length about five times its diameter. Ovipositor nearly as long as the abdomen, the terminal lobes narrowly oval, tapering. Other characters presumably as in the opposite sex.

LIFE HISTORY.

The female midge, with her long ovipositor, places small yellowish eggs just under the sepals of the flower buds or between the folded leaves of the leaf buds. Under favorable temperature conditions these eggs hatch in 2 days, and the young larvæ or maggots immediately attack the buds, extracting the sap and eventually causing the petals and leaves to dry up and die. (Fig. 2.) They grow very rapidly, reaching maturity in from 5 to 7 days, and, when full grown, work their way out of the buds and fall on and enter the ground where they construct small silken cocoons (fig. 1, D) in which they pupate. Adults appear in from 5 to 7 days, and shortly after deposit eggs for the next generation of larvæ or maggots. In confinement the life of an adult is from 1 to 2 days. The total cycle, therefore, under greenhouse conditions, is from 12 to 16 days. About 85 per cent of the adults reared in cages were females.

SEASONAL HISTORY.

Although larvæ or maggots have been observed injuring buds as early as February 22, under normal conditions they do not appear in injurious numbers until June or July. In Washington adults were reared in early May from larvæ which pupated in November. During the warm summer months the generations may mature every two weeks, and overlapping of broods probably takes place. Larvæ were especially injurious at Colgate, Md., during two periods of the year, namely, from the latter part of May to early July and from early September to November 1. On the approach of cold weather the stages are slightly prolonged, and about the latter part of November the larvæ enter the ground and construct overwintering cocoons. No injury has been reported during winter.

FOOD PLANTS.

Roses, especially the hybrid teas, are apparently the only plants attacked by this insect. It has been recorded as infesting the Radiance, Hadley, Russell, Killarney, Ophelia, Hoosier Beauty, Shawyer, My Lady, American Beauty, Uncle John, Joe Hill, Kate Moulton, Bridesmaid, Liberty, Richmond, Mrs. John Laing, Meteor, Madam Chatenay, Ivory, Golden Gate, Wooten, La France, and a sport of the latter, the Duchess of Albany.

EXPERIMENTS IN CONTROL.

At the suggestion of Prof. E. N. Cory a series of experiments, in which the following combinations were used as sprays, was conducted to determine the value of molasses in catching the larvæ, thus pre-

venting their entrance to the soil where pupation takes place: (1) Two pounds (by weight) of molasses, 3 gallons of water, 200 cc. of nicotine sulphate (40 per cent nicotine), and $\frac{1}{2}$ ounce (by weight) of lead arsenate; (2) $1\frac{1}{2}$ pounds (by weight) of molasses, 3 gallons of water, 30 cc. of nicotine sulphate (40 per cent nicotine), and $\frac{1}{2}$ ounce (by weight) of fish-oil soap; (3) 2 pounds (by weight) of molasses,

FIG. 2.—Young leaves and flower buds of roses injured by larvæ of the rose midge.

$2\frac{1}{2}$ gallons of water, 25 cc. of nicotine sulphate (40 per cent nicotine), $\frac{4}{5}$ ounce (by weight) of neutral soap, $1\frac{3}{5}$ ounces (by weight) of lead arsenate, and $6\frac{2}{5}$ ounces of Bordeaux mixture; (4) 2 pounds (by weight) of molasses, $2\frac{1}{2}$ gallons of water, 25 cc. of nicotine sulphate (40 per cent nicotine), and $1\frac{3}{5}$ ounces lead arsenate; (5) 2 pounds (by weight) of molasses, $2\frac{1}{2}$ gallons of water, and $1\frac{3}{5}$ ounces (by weight) of lead arsenate; (6) 2 pounds (by weight) of molasses and $2\frac{1}{2}$ gallons of water.

All of the foregoing experiments were conducted in a commercial greenhouse, and each test represents a 50-foot bed of roses. For the most part the killing results of all six experiments were satisfactory. Unfortunately, however, the molasses served as a medium for the development of sooty mold, and, moreover, where lead arsenate was used an objectionable white deposit developed. The presence of either on cut flowers necessarily would reduce their value and in some instances would eliminate them from the market. As the rose midge usually is present at a season when the grower can ill afford to have objectionable deposits on his cut flowers, it is evident that any of the foregoing combinations will be unsatisfactory, unless some method of counteracting these objectionable features is developed. In addition to the foregoing, 1 part of nicotine sulphate (40 per cent nicotine) to 400 parts of water, with the addition of enough soap to produce suds, was tested. The results of this experiment were very unsatisfactory, fully 95 per cent of the larvæ being uninjured.

To determine the value of tobacco dust in preventing the full-grown larvæ, or grubs, from entering the soil, the following cage experiments were conducted: (1) Soil around caged plants covered with dry tobacco dust; (2) same as former except that the dust was wet. Full-grown larvæ which were placed in the cage containing dry dust were active for 24 hours, but did not go below the surface, whereas the larvæ similarly placed in cage 2 were exceedingly active upon coming in contact with the wet dust, acting as if they were burned, and after from 5 to 8 hours they were all dead. All larvæ used in the check immediately entered the soil.

Having determined a satisfactory method of preventing the entrance of the full-grown larvæ into the soil, all of the rose beds in the infested houses at Colgate, Md., were covered on October 12, 1916, with tobacco dust averaging from one-fourth to one-half inch deep. To prevent the larvæ from entering the dirt walks of the houses, all walks were sprayed with 5 per cent kerosene emulsion. Simultaneously nightly fumigation with tobacco stems was inaugurated and continued until October 30, inclusive, and from that date until November 8 the houses were fumigated every other night. The object of this fumigation was to kill all adults before eggs were deposited.

Although this control work was not undertaken until October 12, its effectiveness was soon apparent, and by the latter part of October it was very difficult to locate an infested bud. Not only was the midge under control, but the owner was enabled to bring on his fall crop earlier than was the case in 1915. On May 7, 1917, these houses were carefully examined, and only 6 larvæ were located, 2 in the buds of the Hadley and 4 in the buds of the Radiance. All plants at this time were in excellent condition and gave promise of pro-

ducing a full crop of flowers. These houses were again carefully examined on June 19, and no injury was to be found on any of the plants which had been infested so severely during the fall of 1916. Moreover, the owner reported that up to June 19 more than twice as many blooms had been cut as during the entire previous year.

The rapid elimination of this pest was due no doubt to two causes, (1) nightly fumigation, which killed off the adults before egg-laying took place, and (2) the application of tobacco dust, which prevented the larvæ from entering the soil. Moreover, the tobacco dust served a dual purpose, since it prevented the larvæ from entering hibernating quarters and at the same time fertilized the soil.

METHODS OF CONTROL.

It is evident from the experiment described above that a severe infestation of the rose midge can be controlled, if not entirely eliminated, in a comparatively brief period by the careful application of tobacco dust on the soil and by persistent nightly fumigation with tobacco, in the form of stems, nicotine papers, or one of the volatile nicotine preparations.[1]

Where earth walks are present, it is advisable to spray the walks also with a 5 or 10 per cent kerosene emulsion.[2]

In the case of light infestations, the midge can be controlled by systematic nightly fumigations with tobacco fumes, which should be continued until all adults disappear; or by a careful application, at the proper season, of tobacco dust. Inasmuch as the broods probably overlap during the summer, there is a possibility that frequent syringing of the plants would cause much of the dust to wash down into the soil before all larvæ matured; hence there is a chance that some would fall on and enter earth where the dust had lost its effectiveness. It would seem, therefore, that the most opportune time to apply the dust, if not accompanied with nightly fumigation, is

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[1] Although tobacco stems have been used in greenhouses from time immemorial they are being replaced rapidly by nicotine paper and the volatile nicotine extract, owing to the fact that the nicotine content of the stems is so variable. Tobacco stems in the proper condition (those which have not been allowed to become wet and dry out) will yield good results. As there is no satisfactory and easy method by which the florist can determine accurately the nicotine content of tobacco stems, however, it will probably be a saving of time and money to use the nicotine papers or the volatile nicotine extracts, in which case the directions on the label of the container should be followed.

[2] Kerosene emulsion (stock solution, 66 per cent oil) is made after the following formula:

Kerosene (coal oil, lamp oil)	gallons	2
Soap (fish-oil or laundry) (or 1 quart soft soap)	pound	½
Water (soft)	gallon	1

First dissolve the soap in boiling water, then remove the vessel from the fire and immediately add the kerosene, thoroughly agitating the mixture until a creamy solution results. The stock solution may be more conveniently made by pouring the mixture into the tank of a spray pump and pumping the liquid through the nozzle back into the tank for five minutes. A 10 per cent solution can be made by adding to each gallon of the stock solution about 5⅔ gallons of water. In some regions the water is "hard," and in such cases it should be broken with a little lye, or rain water should be used.

during the latter part of October or the first three weeks of November, at which season the last generation of larvæ leaves the plants, enters the ground, and constructs overwintering cocoons. If dependance is placed on the dust alone, it is imperative that the application be so timed as to be on the soil before the larvæ seek winter quarters. No hard and fast rule governing the date of this application can be recommended for all localities, since temperature naturally influences the final disappearance of the larvæ.

PRECAUTIONARY MEASURES.

The rose midge can be kept out of greenhouses if proper precautions are exercised. Under no condition should infested plants be taken into a house free from this pest. Plants should not be purchased knowingly from firms which carry infested stock, and should be bought with the understanding that they are free from the midge either in the buds or in the soil. Before new stock is placed in a house, all plants should be examined carefully, and suspicious ones destroyed or returned to the shipper.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 779

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

Washington, D. C. PROFESSIONAL PAPER June 24, 1919

THE GRAIN BUG.[1]

By D. J. Caffrey and Geo. W. Barber,

Scientific Assistants, Cereal and Forage Insect Investigations.

CONTENTS.

INTRODUCTION.

During the past few years the grain bug, (*Pentatoma*) *Chlorochroa sayi* Stål, has become a pest of considerable importance to the farmers of the intermountain and southwestern States. It is now regarded as a serious menace to the growing of wheat and other small grains in both the irrigated and nonirrigated districts within the area of its distribution.

The vital damage is caused by the piercing of the newly formed heads of cereals and the feeding on the liquid contents, by which the formation of the grain is prevented or its weight greatly reduced.

The recent development of *C. sayi* as an economic pest is due to an artificial change in its environment and food plants. This condition has been brought about by the cultivation of large areas formerly devoted to grazing, which practically eliminated many of the native food plants and caused the insect to attack some of the crops grown in its former habitat. The change to more succulent food plants, together with the better facilities for hibernation in the cultivated areas, resulted in a marked increase of the pest.

[1] The observations detailed in this bulletin were made by the senior author in 1915 and by the junior author in 1916 during a destructive outbreak of the species in northeastern New Mexico and adjacent territory. The experiments were carried on at the Field Laboratory of the Bureau of Entomology located at Maxwell, N. Mex.

Mr. E. H. Gibson, of the Bureau of Entomology, kindly redescribed the adult of the species and assisted in the preparation of notes on the history, synonymy, distribution, food plants, and bibliography.

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Weather influences and the work of parasites in each locality where damage has occurred generally have restricted the destructive outbreaks of *C. sayi* to periodic intervals of two or three years. Since 1911, however, its activities have been reported with increasing frequency each year in widely separated districts within its range. This development indicates clearly the possibility that the species may become economically more important in the future than it has been in the past.

HISTORY.

The grain bug belongs to the rather extensive heteropterous family Pentatomidae, the members of which are popularly known by the expressive term of "stink-bugs." It was first authentically described under the name *Lioderma*, subg. *Chlorochroa*, *sayi* by Stål (1)[1] in 1872. In the same year Uhler (2) described a species under the name *Pentatoma granulosa*, which later proved to be synonymous with Stål's *L. sayi*. In 1904 Van Duzee (3) placed the species in the subgenus Chlorochroa of the genus Pentatoma. In 1909 Kirkaldy (4) placed the subgenus Chlorochroa under the genus Rhytidolomia. In 1916 Van Duzee (7) removed Chlorochroa from Rhytidolomia and raised it to generic rank, listing the species under consideration as *Chlorochroa sayi* Stål.

The first recorded damage by *Chlorochroa sayi* is found in the unpublished notes of the Bureau of Entomology, several farmers of the upper Gila and Salt River Valleys of Arizona having reported it, in May, 1903, as very destructive to wheat and barley. One farmer wrote that there was an average of about 10 bugs to each head of barley in his 40-acre field. After badly damaging this area the insects had moved to an adjoining wheat field, these conditions being typical for a distance of about 30 miles along the upper Gila Valley. In reply to an inquiry by Dr. L. O. Howard the following note was received on June 5, 1903, from Dr. R. H. Forbes, director of the Arizona Agricultural Experiment Station: "We have kept track of the outbreak of *Lioderma sayi* in Arizona. The worst outbreak was upon the upper Gila River, between Safford and Fort Thomas, but a great many specimens were also to be found in the Salt River Valley." In July of the same year reports of damage and specimens of the insect were received from the San Juan Valley in southwestern Colorado. In 1905 and 1906 this species was very numerous in the wheat fields of northern Texas, but no widespread damage was reported. Dr. A. W. Morrill (6) published an account of the complete loss of 13 acres of milo maize near Phoenix, Ariz., in September, 1911, as a result of depredations by

[1] Figures in parentheses refer to "Literature cited," p. 34.

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In May, 1912, Mr. C. N. Ainslie received specimens of *Chlorochroa sayi* and accounts of injury to the heads of spring wheat from a correspondent at Tucumcari, N. Mex. Mr. Ainslie also notes that while making field investigations in Utah during 1912 the farmers in four widely separated districts of the State reported that the grain bug had seriously damaged wheat and alfalfa seed during the years immediately prior to 1912.

Mr. H. E. Smith records widespread damage to barley and oats in the Pecos River Valley of New Mexico during 1912 and 1913. At the same time Mr. E. G. Kelly found similar conditions prevailing in the "dry-farming" section near Clovis, N. Mex., and in the vicinity of Liberal, Kans.

In July, 1913, a correspondent wrote from Cloudcroft, N. Mex., that the grain bug had ruined 12 acres of rye on his ranch and that the farmers of that section had cut the barley for hay to prevent the destruction of its grain by the invading hordes of the insect. Similar damage was reported from southern Utah during the same month. In 1914 and 1915 continued reports were received of depredations by the grain bug from various localities in Arizona, New Mexico, Texas, and Colorado.

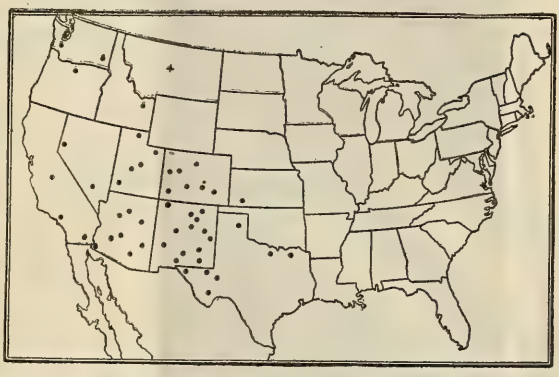

FIG. 1.—Map showing distribution of the grain bug (*Chlorochroa sayi*) in the United States. The dots indicate definite localities; the cross in the State of Montana is based on the statement of Van Duzee (3) that his study material included specimens from Montana. He does not indicate the locality.

DISTRIBUTION.

In the United States *C. sayi* is distributed generally throughout the Upper and Lower Austral zones of the States west of the Great Plains area, including Washington, Oregon, California, Idaho, Nevada, Montana, Utah, Colorado, Arizona, New Mexico, western Kansas, and the western and northern parts of Texas. (See fig. 1.) These data were secured from personal collections in the field and by an examination of the collections, notes, correspondence, and literature of the United States National Museum and the Bureau of Entomology, as well as from other available literature.

The insect is found at varying altitudes ranging from 9,300 feet at Silverton, Colo., to below sea level in the Imperial Valley of California.

FOOD PLANTS.

The nymphs and adults of *C. sayi* have been observed to feed upon the fruit and seeds of a wide range of cultivated plants, including wheat, barley, rye, oats, winter emmer, spelt, milo maize, kafir corn, feterita, alfalfa, Sudan grass, cotton, buckwheat, peas, beans, cabbage, tomato, and lettuce. Among the native food plants of the species are Russian thistle (*Salsola tragus* L.), mallow (*Malva parviflora* L.), pigweed (*Amaranthus* spp.), wild oats (*Stipa* spp.), lamb's-quarters (*Chenopodium* spp.), sheepweed (*Gutierrezia* spp.), and a species of the honeysuckle (*Lonicera involucrata* Banks).

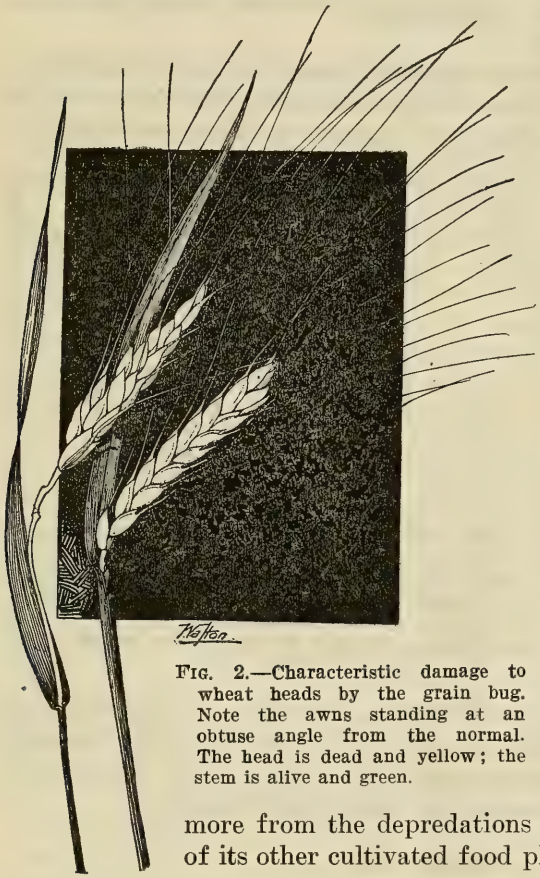

FIG. 2.—Characteristic damage to wheat heads by the grain bug. Note the awns standing at an obtuse angle from the normal. The head is dead and yellow; the stem is alive and green.

Wheat, barley, and rye appear to suffer more from the depredations of *C. sayi* than do any of its other cultivated food plants.

CHARACTER OF INJURY.

EXTERNAL APPEARANCE OF INJURED PLANTS.

The heads of small grains that have been injured by *C. sayi* are conspicuous in the field, especially those of wheat, barley, rye, and oats. Soon after attack, and long before the normal period of ripening is reached, the damaged heads assume a dull yellowish-white color and in this condition are in sharp contrast to the bright green of the undamaged heads. They appear normal in size with the ex-

ternal appearance of ripened heads, but upon being pressed between the fingers are found to be nearly, if not entirely, empty. With the bearded varieties, the "beards" or awns stand out nearly at right angles from the head instead of in the vertical position assumed under normal conditions. (See fig. 2.)

The stem is generally alive and green from the base to a point within 5 or 6 inches of the head, but is dead and yellow above this point. Upon grasping the head and exerting a slight pull, the stem breaks at the junction of the living and dead portions. During a wind or rain storm many of these stems are broken and the heads fall to the ground. The damage caused by *C. sayi* is frequently of such a nature that an unobserving person may attribute its effects to hail or other weather influences.

In the case of milo maize, feterita, and many of the native food plants, the external appearance of injured plants does not differ markedly from that of the normal.

INTERNAL APPEARANCE OF INJURED HEADS.

The grains of affected heads are shriveled in appearance and very much reduced in size and weight. In some cases only a diminutive grain remains. This follows as the natural result of the removal by the insect of the liquid contents of the grain while still in the "milk stage."

The grains from injured heads of some plants, including milo maize, appear normal even when damaged, but are very much reduced in weight, lack the nutritive properties of normal grains, and are totally unfit for seed.

REDUCTION IN YIELD.

The percentage of reduction in yield through depredations of the grain bug is a point not always possible of determination. Frequently the extent of the damage is not appreciated by the grower until the crop is thrashed. Then the poor quality of the grain becomes evident and the yield is far below expectations. In extreme cases entire fields of small grains have been destroyed completely and the crop was not worth harvesting. As previously stated, Dr. A. W. Morrill (6) records the complete loss of 13 acres of milo maize from grain-bug attack at Phoenix, Ariz., in 1911, and 12 acres of rye were completely ruined at Cloudcroft, N. Mex., in 1913. From 70 to 90 per cent of an alfalfa seed crop was destroyed at Barstow, Tex., in 1911. Mr. H. E. Smith records that at Roswell, N. Mex., in 1913, at least two-thirds of the barley heads were ruined in fields that normally would yield from 40 to 60 bushels per acre. At Porterville, Tex., in 1913, the wheat in a 150-acre field which promised a

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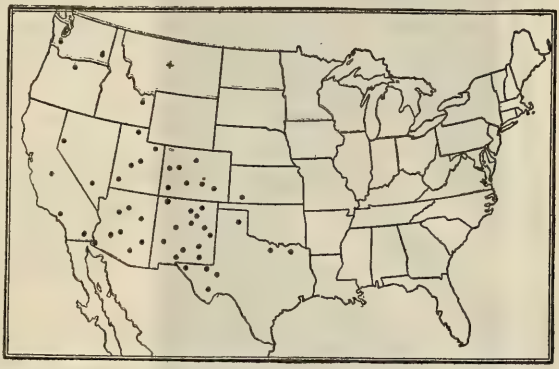

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FOOD PLANTS.

The nymphs and adults of *C. sayi* have been observed to feed upon the fruit and seeds of a wide range of cultivated plants, including wheat, barley, rye, oats, winter emmer, spelt, milo maize, kafir corn, feterita, alfalfa, Sudan grass, cotton, buckwheat, peas, beans, cabbage, tomato, and lettuce. Among the native food plants of the species are Russian thistle (*Salsola tragus* L.), mallow (*Malva parviflora* L.), pigweed (*Amaranthus* spp.), wild oats (*Stipa* spp.), lamb's-quarters (*Chenopodium* spp.), sheepweed (*Gutierrezia* spp.), and a species of the honeysuckle (*Lonicera involucrata* Banks).

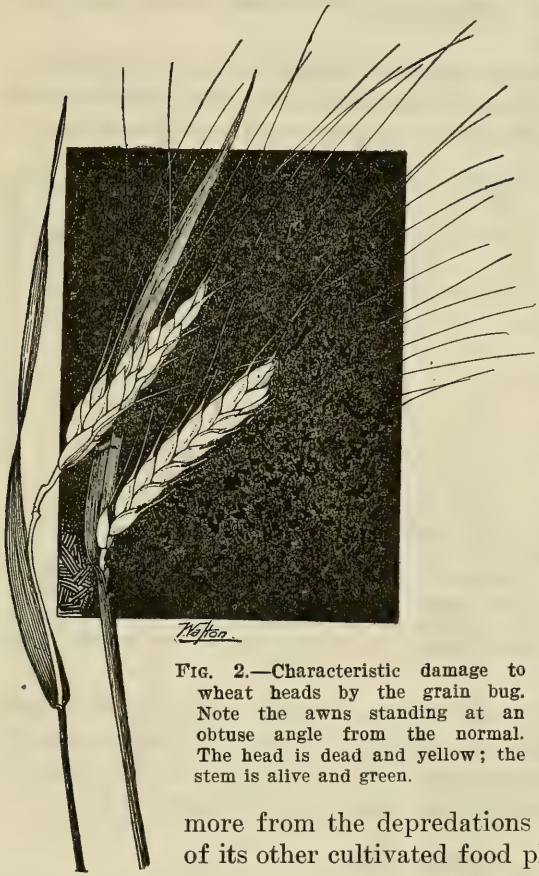

FIG. 2.—Characteristic damage to wheat heads by the grain bug. Note the awns standing at an obtuse angle from the normal. The head is dead and yellow; the stem is alive and green.

Wheat, barley, and rye appear to suffer more from the depredations of *C. sayi* than do any of its other cultivated food plants.

CHARACTER OF INJURY.

EXTERNAL APPEARANCE OF INJURED PLANTS.

The heads of small grains that have been injured by *C. sayi* are conspicuous in the field, especially those of wheat, barley, rye, and oats. Soon after attack, and long before the normal period of ripening is reached, the damaged heads assume a dull yellowish-white color and in this condition are in sharp contrast to the bright green of the undamaged heads. They appear normal in size with the ex-

ternal appearance of ripened heads, but upon being pressed between the fingers are found to be nearly, if not entirely, empty. With the bearded varieties, the "beards" or awns stand out nearly at right angles from the head instead of in the vertical position assumed under normal conditions. (See fig. 2.)

The stem is generally alive and green from the base to a point within 5 or 6 inches of the head, but is dead and yellow above this point. Upon grasping the head and exerting a slight pull, the stem breaks at the junction of the living and dead portions. During a wind or rain storm many of these stems are broken and the heads fall to the ground. The damage caused by *C. sayi* is frequently of such a nature that an unobserving person may attribute its effects to hail or other weather influences.

In the case of milo maize, feterita, and many of the native food plants, the external appearance of injured plants does not differ markedly from that of the normal.

INTERNAL APPEARANCE OF INJURED HEADS.

The grains of affected heads are shriveled in appearance and very much reduced in size and weight. In some cases only a diminutive grain remains. This follows as the natural result of the removal by the insect of the liquid contents of the grain while still in the "milk stage."

The grains from injured heads of some plants, including milo maize, appear normal even when damaged, but are very much reduced in weight, lack the nutritive properties of normal grains, and are totally unfit for seed.

REDUCTION IN YIELD.

The percentage of reduction in yield through depredations of the grain bug is a point not always possible of determination. Frequently the extent of the damage is not appreciated by the grower until the crop is thrashed. Then the poor quality of the grain becomes evident and the yield is far below expectations. In extreme cases entire fields of small grains have been destroyed completely and the crop was not worth harvesting. As previously stated, Dr. A. W. Morrill (6) records the complete loss of 13 acres of milo maize from grain-bug attack at Phoenix, Ariz., in 1911, and 12 acres of rye were completely ruined at Cloudcroft, N. Mex., in 1913. From 70 to 90 per cent of an alfalfa seed crop was destroyed at Barstow, Tex., in 1911. Mr. H. E. Smith records that at Roswell, N. Mex., in 1913, at least two-thirds of the barley heads were ruined in fields that normally would yield from 40 to 60 bushels per acre. At Porterville, Tex., in 1913, the wheat in a 150-acre field which promised a

yield of from 50 to 60 bushels, thrashed only 22 bushels of very inferior grain per acre.

During 1915 when the grain bug was under close observation in northeastern New Mexico the visible damage before harvest varied in many of the fields from only a trace to 50 per cent of the heads, the average being about 10 per cent. The full extent of the damage was not appreciated until harvest, when the poor quality, reduced yield, and light weight of the grain were sources of general complaint among the farmers. In one instance under consideration a carload of oats averaged only 18 pounds per bushel.

FIG. 3.—The grain bug: Eggs. Above, much enlarged; below, highly magnified.

DESCRIPTION.

THE EGG.[1]

Length 1.1 to 1.2 mm.; width at widest part 0.88 to 0.93 mm.; width at bottom 0.57 to 0.66 mm. The egg (fig. 3) is irregularly ovoid in form, with irregular gray areas on the lateral surface, in appearance resembling froth. Viewed from above, three white circles appear, inclosing a central dull-gray area and two circular bands of the same color.

Described from 15 eggs taken from as many different clusters.

NYMPHS.[1]

FIRST INSTAR.

Length 1.1 to 1.54 mm.; width of thorax 0.88 to 0.935 mm.; width of abdomen 0.935 to 1.072 mm.

Dorsally: Head black, finely punctate, anterior margin sparsely pubescent; eyes black, prominent; antennæ 0.77 to 1.88 mm. in length, light brown, three terminal segments sparsely pubescent. Thorax black, finely punctate, with deep convolutions between its divisions and down the median line. Abdomen brown-black in color, mid-dorsal section occupied by a narrow black band; location of scent glands indicated by two black transverse areas; a single black area within a yellow border on the lateral margin of each segment and a series of three irregular yellow-white markings converging toward the apex of the abdomen. The lateral margins of the abdomen and thorax are greatly depressed and form a shelf-like division between the ventral and dorsal surfaces. This is distinct from the connexivum of adult Heteroptera. The "shelf" persists throughout the nymphal period. Edge of "shelf" sparsely pubescent in this instar.

FIG. 4.—The grain bug: Nymph, first instar. Much enlarged.

[1] Original description.

Ventrally: Color uniform black, divisions of "shelf" white, rostrum light brown, extending three-fourths length of venter; legs black. The legs are sparsely pubescent in all stages of the insect.

Described from 15 specimens.

SECOND INSTAR.

Length 2.2 to 2.53 mm.; width of thorax 1.21 to 1.275 mm.; width of abdomen 1.54 to 2.117 mm.

During the development of the nymphs in the second instar a change occurs in the color, markings, and pubescence which is not accompanied by any visible molt. The description of the nymphs in the early stages of this instar (fig. 5) follows:

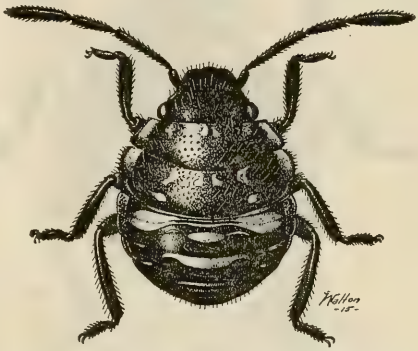

FIG. 5.—The grain bug: Nymph, second instar (in early stages of the instar). Much enlarged.

Dorsally: Head black, finely punctate, sparsely pubescent throughout; eyes dark brown, prominent; antennæ 1.375 to 1.485 mm. in length, light salmon or brown, three terminal segments sparsely pubescent. Thorax black, coarsely punctate, sparsely pubescent on dorsum and at edge of "shelf"; four irregular yellow-white areas on anterior borders of prothorax and mesothorax, with two small dots of same color on posterior border of mesothorax; "shelf" white. Abdomen black, with a pale yellow double band extending transversely across the anterior border and becoming enlarged near the margin; posterior to this band the mid-dorsal section is occupied by five irregular bands of the same color and two brown, slightly raised, elongated, elliptical areas bearing the scent glands; posterior margin sparsely pubescent; "shelf" white.

Ventrally: Uniform black except the white "shelf"; rostrum light brown, extending three-fourths length of venter; legs black.

FIG. 6.—The grain bug: Nymph, second instar (in later stages of the instar). Much enlarged.

The following changes are observed in late stages of this instar (fig. 6):

Dorsally: Head pubescent only on anterior border, anterior half impressed with two parallel sutures on each side of median line. These parallel sutures persist in all the remaining stages of the insect. Antennæ black. Thorax with a faint tinge of green, no pubescence, finely punctate, no yellow-white areas. Abdomen with decided tinge of green; a narrow transverse yellow-white band occupying two-thirds of the anterior border, and posterior to this band the mid-dorsal section occupied by a small circular yellow-white area, two curved bands of the same color, and two wider black irregularly ovoid areas, bearing the scent glands; "shelf" red-orange.

Ventrally: "Shelf" red-orange on the abdomen.

Described from 15 specimens.

THIRD INSTAR.

Length 3.08 to 3.19 mm.; width of thorax 1.925 to 2.035 mm.; width of abdomen 2.365 to 2.805 mm.

Dorsally: Head black, finely punctate, slightly pubescent; eyes black, prominent; antennæ 1.925 to 1.98 mm. in length, black, two terminal segments very finely pubescent. Thorax black with distinct tinge of green, coarsely punctate; "shelf" white during early stage of instar, later becoming orange in color. Abdomen dark green and bearing approximately the same markings as later stages of preceding instar, and black coarse punctations; segmentation emphasized by black lines in this and in the remaining nymphal instars; "shelf" orange color.

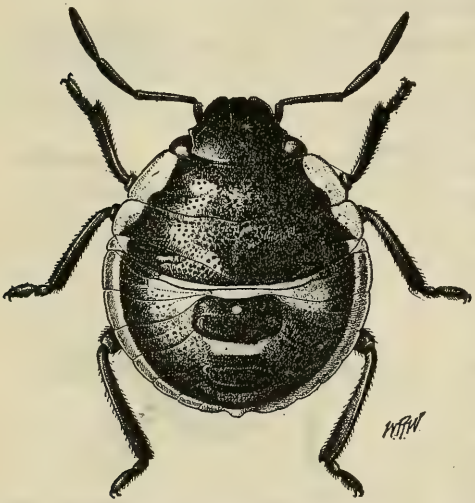

FIG. 7.—The grain bug: Nymph, third instar. Much enlarged.

Ventrally: Head and thorax green. Abdomen pale green, a black circular area on each of the four terminal segments; anal opening black. These black areas persist on the venter of the remaining nymphal instars. "Shelf" orange on both thorax and abdomen. Rostrum green, extending slightly more than one-half length of venter. Legs: Coxæ, trochanters, and femora green; tibiæ and tarsi brown.

Described from 7 specimens.

FOURTH INSTAR.

Length 5.2 to 6.6 mm.; width of thorax 3.1 to 3.75 mm.; width of abdomen 3.8 to 4.9 mm.

Dorsally: Head pale green, finely punctate; eyes reddish black, not so prominent as in preceding instars; antennæ 3.4 to 3.7 mm. in length, dark brown or black. Thorax pale green with darker coarse punctations; wing pads visible as slightly raised areas on both sides of thorax; "shelf" white with a red-orange edge. Abdomen pale green; punctations numerous, coarse and darker green in color; a narrow yellow transverse band occupying one-half median portion of abdomen on anterior border, and posterior to this band the mid-dorsal section occupied by a short narrow yellow band, four circular areas of the same color, and two brown crescentic projections bearing the scent glands; black coarse punctations more numerous than in preceding instar; "shelf" white with red-orange edge.

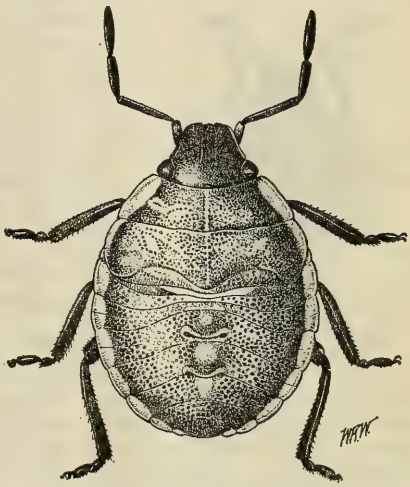

FIG. 8.—The grain bug: Nymph, fourth instar. Much enlarged.

Ventrally: Uniform pale green, with black punctations. "Shelf" orange on both thorax and abdomen. Rostrum green with brown tip and extending one-half the length of venter. Legs: Coxæ, trochanters, and femora pale green; tibiæ and tarsi light brown.

Described from 11 specimens.

FIFTH INSTAR.

Length 8.9 to 10.6 mm.; width of thorax 4.3 to 4.8 mm.; width of abdomen 5.3 to 7 mm.

Dorsally: Head pale green, finely punctate; eyes brown, surrounded by pale green area; antennæ 4.5 to 5.2 mm. in length, black or brown, peduncle light green, articulation of segments pale green. Thorax green with black punctations; wing pads black or nearly so; "shelf" white to orange. Abdomen pale green with black punctations and bearing approximately the same marking as preceding instar; "shelf" white with more pronounced orange edge than on thorax, not so prominent as in preceding instars.

Ventrally: Same as the preceding instar. Rostrum extending to posterior coxæ. Legs: Tarsi and outer fourth of tibiæ black, remaining portions of legs pale green, tarsi and tibiæ bearing numerous black spines.

Described from 15 specimens.

FIG. 9.—The grain bug: Nymph, fifth instar. Much enlarged.

THE ADULT.

The following is the description by Stål (1).

5. **L[ioderma] (Chlorochroa) Sayi** STÅL.—Ovalis, dilute viridis, subtus pallidior, superne pectoreque sat dense distincteque punctata, ventre subtilius punctato; antennis nigris, articulo basali virescente; limbo laterali antico thoracis, limbo costali thoracis, apice scutelli, margine abdominis, coxis, trochanteribus femoribusque basin versus pallide sordide flavescentibus; callis rugulisque parvis sparsis, in thorace scutelloque obsoletis, in corio distinctioribus, nec non maculis tribus laevigatis subcallosis basalibus scutelli viridi-albicantibus; membrana alisque decoloribus; marginibus imis lateralibus anticis thoracis et margine imo abdominis lutescentibus; tarsis apicem versus fuscis. ♀. Long. 11, Lat. 6 1/3 mill.

Patria: California. (Mus. Holm.).

Praecedenti affinis, notis allatis formaque angustiore divergens.

A redescription of the adult, by Mr. E. H. Gibson, of the Bureau of Entomology, is given below.

Distance between eyes equaling almost two-thirds length of head. Head closely punctate above. Tylus and juga of the same length. Anterior margin

of head slightly reflexed or cariniform. First antennal segment less than one-half as long as second; second, third, fourth, and fifth segments of nearly the same length, the second slightly the longest and most slender. Bucculæ long and prominent. Rostrum extending to hind coxæ.

Pronotum coarsely punctured and appearing somewhat rugose. Lateral margins reflexed or cariniform. Callosities prominent.

Scutellum coarsely punctured and appearing somewhat rugose, like the pronotum. Three large prominent callosities on anterior border, one at each anterio-lateral angle, and one at the middle. Apex bluntly rounding.

Elytra more finely punctured than scutellum with many small callous spots. Membrane clear.

General form elongate. Average size of female 13.5 mm.; males somewhat smaller. The general size varies considerably.

Color normally a decided deep green, but varying from a pale yellowish green to reddish brown. Numerous small white calloused spots on pronotum, scutellum, and elytra. Lateral border of pronotum, basal portion of costal border of elytra, the three large callouses on anterior border of scutellum, and apex of scutellum yellow or red. As noted, the color varies greatly but the numerous light colored callous spots are characteristic. Antennæ black except for basal segment and basal half of second segment, which are green. Pale yellowish green beneath. Abdomen above black except borders, which are yellow and unmarked.

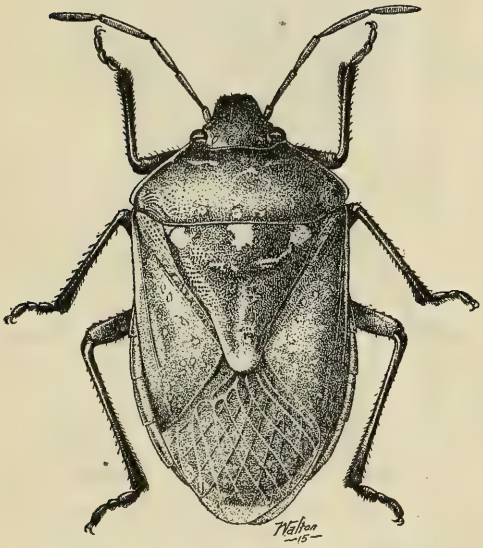

FIG. 10.—The grain bug: Adult. Much enlarged.

LIFE HISTORY AND DEVELOPMENT.

The observations on the life history and development of *Chlorochroa sayi*, as detailed herein, were made at an altitude of about 6,000 feet in northeastern New Mexico. These details probably would vary considerably under the different conditions of humidity, latitude, and altitude within the distribution of the insect.

EGG.

PERIOD OF INCUBATION.

The period of incubation is from 4 to 13 days in length, depending upon weather influences, the average throughout the season being about 9 days. During the warm summer months the egg period occupies an average of from 5 to 7 days.

RELATION OF TEMPERATURE TO INCUBATION.

In laboratory experiments and in the field it was observed that variations in temperature had a pronounced influence in determining the length of the egg period. In one experiment half of a newly deposited egg cluster hatched in 4 days when exposed to a maximum daily temperature of 90° F. while the remaining half of the same egg cluster which was exposed to a maximum daily temperature of 70° F. required 7 days to complete its period of incubation. (See Table I.)

TABLE I.—*Relation of temperature to incubation and nymphal development in Chlorochroa sayi.*

	Incubation period.	First instar.	Second instar.
	Days.	*Days.*	*Days.*
Maximum daily temperature of 70° F.	7	9	14
Maximum daily temperature of 90° F.	4	4	7
Difference for 20° F. of temperature	3	5	7

DETAILS OF HATCHING.

When nearly ready to hatch, the eggs assume a darker color than during the earlier stages of their development. Upon dissecting one of these eggs it is found that the fully developed nymph is inclosed within a delicate transparent membrane. On the outside of this membrane just under the lid of the egg, and at a point opposite the vertex of the head of the inclosed nymph, is a black, chitinized T-shaped structure which functions as a shell burster. The curved top of the T, or shell burster, follows a curved line running from eye to eye of the nymph over the vertex of the head. The shank of the T follows the median dorsal line of the nymph posteriorly. A short, stout spine occupies about one-third of the median portion of the T at the point where the lines intersect. This spine is directed at the suture between the lid and the neck of the egg at a point opposite its hinge. During the process of hatching the struggles of the nymph against the shell burster exert a strong lifting pressure on this spine and the lid of the egg is partially raised. At the same time the inclosing membrane splits just back of the shell burster and slips forward over the head of the nymph. As the integument of the nymph is very soft, the emergence is by slow periodic movements apparently exerted from within the body of the nymph. The first portion of the nymph to be free is the first pair of legs, followed by the antennæ, rostrum, second pair of legs, third pair of legs, head, thorax, and abdomen in the order named.

In observations on the hatching of 8 individual nymphs, the time required for emergence varied from 14 to 40 minutes, the average being 20 minutes. The newly hatched nymph is capable of locomotion soon after completing emergence but generally remains on or near its parent egg cluster until the second instar is reached. All normal eggs in the same egg cluster generally hatch within a 24-hour period.

PROPORTION OF EGGS HATCHING IN THE FIELD.

Unless destroyed by parasites or predacious enemies, the proportion of eggs of *Chlorochroa sayi* hatching in the field is very high. Occasionally a few eggs in otherwise normal clusters were prevented from hatching by being deposited wrong end up. A few eggs, too, were deposited on top of the main egg cluster, which invariably prevented the lower eggs from hatching. Very few infertile egg clusters were collected in the field. Abnormal weather conditions prolonged the period of incubation but appeared to have no other injurious effects on the eggs.

PROPORTION OF EGGS HATCHING IN THE LABORATORY.

In one laboratory experiment a total of 1,068 eggs were deposited by 30 females confined in life-history cages. Of this number a total of 981 eggs, or 91.88 per cent, hatched. The remaining 8.12 per cent were probably somewhat affected by the abnormal cage conditions.

NYMPHS.

DURATION OF NYMPHAL STAGES.

The prevailing temperature conditions have a marked influence in controlling the duration of the nymphal stages of *Chlorochroa sayi* in the field and in life-history cages. During the period from July 5 to August 18, 1916, a total of 17 nymphs were reared from egg to adult. (See Table II.) In this series of cages the first instar occupied 5 days; the second instar, from 7 to 9 days with an average of 8.2 days; the third instar, from 5 to 7 days with an average of 6.4 days; the fourth instar, from 7 to 10 days with an average of 8.2 days; and the fifth instar occupied from 13 to 17 days, the average being 14.9 days. From 42 to 44 days were required to complete the nymphal period, the average being 42.7 days.

TABLE II.—*Duration of nymphal instars of Chlorochroa sayi in period from July 5 to August 18, 1916.*

Female No.	Nymphs hatched.	First molt.	First instar.	Second molt.	Second instar.	Third molt.	Third instar.	Fourth molt.	Fourth instar.	Fifth molt to adult.	Fifth instar.	Total nymphal period.
			Days.		*Days.*		*Days.*		*Days.*		*Days.*	*Days.*
1....	July 5	July 10	5	July 19	9	July 24	5	Aug. 1	8	Aug. 16	15	42
2....	...do...	...do....	5	...do....	9	...do....	5	...do...	8	...do....	15	42
3....	...do...	...do....	5	...do....	9	July 25	6	...do...	7	Aug. 17	16	43
4....	...do...	...do....	5	July 17	7	July 24	7	...do...	8	Aug. 16	15	42
5....	...do...	...do....	5	...do....	7	...do....	7	...do...	8	Aug. 18	17	44
6....	...do...	...do....	5	July 18	8	July 25	7	Aug. 3	9	Aug. 17	14	43
7....	...do...	...do....	5	July 19	9	...do....	6	Aug. 1	7	Aug. 16	15	42
8....	...do...	...do....	5	July 18	8	...do....	7	Aug. 2	8	Aug. 17	15	43
9....	...do...	...do....	5	July 19	9	...do....	6	Aug. 3	9	...do....	14	43
10....	...do...	...do....	5	July 18	8	...do....	7	...do...	9	...do....	14	43
11....	...do...	...do....	5	...do....	8	...do....	7	Aug 2	8	...do....	15	43
12....	...do...	...do....	5	...do....	8	...do....	7	...do...	8	Aug. 18	16	44
13....	...do...	...do....	5	...do....	8	July 24	6	Aug. 1	8	Aug. 17	16	43
14....	...do...	...do....	5	...do....	8	July 25	7	Aug. 3	9	Aug. 16	13	42
15....	...do...	...do....	5	...do....	8	July 24	6	...do...	10	Aug. 17	14	43
16....	...do...	...do....	5	...do....	8	...do....	6	Aug. 1	8	Aug. 16	15	42
17....	...do...	...do....	5	...do....	8	July 25	7	Aug. 2	8	Aug. 17	15	43
Averages.....			5	.....	8.2	.....	6.4	.....	8.2	.....	14.9	42.7

Later in the season during a period of cooler weather, from August 10 to September 30, 1916, the duration of the nymphal stages of 25 nymphs averaged 7 days for the first instar, 14 days for the second instar, and 18 days for the third instar. (See Table III.) This series of experiments was discontinued on October 3.

TABLE III.—*Duration of nymphal instars of Chlorochroa sayi in period from Aug. 16 to Sept. 30, 1916.*[1]

No.	Nymph hatched.	First molt.	First instar.	Second molt.	Second instar.	Third molt.	Third instar.
			Days.		*Days.*		*Days.*
1	Aug. 16	Aug. 23	7	Sept. 7	15	Sept. 22	15
2	....do.....	....do.....	7	Sept. 6	14	Sept. 23	17
3	....do.....	....do.....	7	Sept. 7	15	Sept. 27	20
4	....do.....	....do.....	7	....do.....	15	Sept. 23	16
5	....do.....	....do.....	7	Sept. 6	14	....do.....	17
6	....do.....	....do.....	7	Sept. 5	13	Sept. 22	17
7	....do.....	....do.....	7	Sept. 7	15	Sept. 26	19
8	....do.....	....do.....	7	Sept. 8	16	....do.....	18
9	....do.....	....do.....	7	Sept. 6	14	Sept. 24	18
10	....do.....	....do.....	7	Sept. 5	13	Sept. 23	18
11	....do.....	....do.....	7	Sept. 7	15	Sept. 28	21
12	....do.....	....do.....	7	....do.....	15	Sept. 26	19
13	....do.....	....do.....	7	Sept. 5	13	Sept. 25	20
14	....do.....	....do.....	7	Sept. 7	15	Sept. 26	19
15	....do.....	....do.....	7	....do.....	15	Sept. 30	23
16	....do.....	....do.....	7	Sept. 6	14	Sept. 24	18
17	....do.....	....do.....	7	....do.....	14	Sept. 26	20
18	....do.....	....do.....	7	Sept. 7	15	Sept. 25	18
19	....do.....	....do.....	7	....do.....	15	Sept. 22	15
20	....do.....	....do.....	7	....do.....	15	Sept. 25	18
21	....do.....	....do.....	7	Sept. 6	14	Sept. 23	17
22	....do.....	....do.....	7	Sept. 7	15	Sept. 22	15
23	....do.....	....do.....	7	Sept. 6	14	Sept. 25	19
24	....do.....	....do.....	7	....do.....	14	Sept. 22	16
25	....do.....	....do.....	7	Sept. 8	16	Sept. 27	19
Averages.....			7	.....	14.5	.....	18.08

[1] Discontinued Oct. 3, 1916.

Similar results were obtained as a result of life-history experiments during 1915.

The death rate of nymphs under observation in the laboratory was very high and increased the difficulty in obtaining data on the length of the different stages, but it is believed that the durations of the instars given above coincide very closely with the actual periods occupied by the nymphs in the field.

DETAILS OF MOLTING.

When the nymph is preparing to molt it generally assumes a position with the head downward. After a quiescent period varying from 15 to 50 minutes the process of molting begins. The thorax first splits down the median dorsal line, then the integument connecting the dorsal plates of the head and thorax splits transversely, allowing the head to fall forward. The thoracic region now becomes elevated, as a result of pressure exerted from within, and the split in the molting skin more pronounced. This causes a transverse separation of the integument connecting the dorsal plates of the thorax and abdomen to a point nearly as far as the lateral edges of the dorsal thoracic sclerites. The molting nymph first extracts the head and its appendages and then the first, second, and third pairs of legs. As soon as the legs are free they are used as a lever in extracting the remainder of the thorax and abdomen from the molted skin. In four instances under observation the process of molting required from 9 to 12 minutes.

The newly molted nymph appears to be prepared to resume its activities within a few moments after the completion of its molt.

With the exception of the ruptures noted above, the cast nymphal skin remains intact and greatly resembles a living nymph.

RELATION OF TEMPERATURE TO NYMPHAL DEVELOPMENT.

In order to determine the relation of temperature to nymphal development an equal number of nymphs hatching at the same time from the same egg cluster were kept under maximum daily temperatures of 70° and 90° F., respectively. The nymphs developing under the lower temperature required an average of 5 days longer for the first instar and 7 days longer for the second instar. (See Table I.) It is evident that cool weather retards nymphal development to a marked degree.

ADULTS.

PERIOD BETWEEN MATURITY AND BEGINNING OF OVIPOSITION.

The ovaries of newly matured females do not contain eggs. In a series of laboratory experiments wherein pairs of reared adults were confined in individual cages, the minimum period between maturity

and oviposition was 41 days. This is probably longer than the period required under field conditions, judging from the number of generations each year. The females maturing late in the season do not oviposit until the following spring.

PROPORTION OF SEXES.

Under field conditions the females of *Chlorochroa sayi* are slightly more abundant than the males. In a total of 564 adults, collected from various habitats throughout the active season, 313 were females and 251 were males. (See Table IV.)

TABLE IV.—*Proportion of sexes of Chlorochroa sayi in different habitats throughout the active season.*

Date.	Habitat.	Number of males.	Number of females.	Total adults.
1916				
May 9	Under rubbish	6	12	18
May 10	.....do	81	94	175
May 13	.....do	1	4	5
May 16	.....do	5	13	18
June 29	.....do	4	4	8
June 30	Wheat heads	28	22	50
July 12	Under Russian thistle of previous year	12	6	18
July 14	On wheat heads	5	8	13
July 20	On wheat and thistle	3	4	7
July 24	.....do	6	5	11
Aug. 1	On Russian thistle in waste areas of recently cut wheat field	10	12	22
Aug. 2	.....do	9	20	29
Do.	On oat heads	.....	6	6
Aug. 3	On Russian thistle	3	9	12
Aug. 4	.....do	12	11	23
Aug. 17	.....do	8	8	16
Aug. 24	.....do	2	8	10
Sept. 28	In winter quarters	2	6	8
Sept. 29	.....do	20	20	40
Oct. 2	.....do	34	41	75
Total		251	313	564

LONGEVITY OF REARED ADULTS.

A series of reared adults kept in life-history cages lived a minimum of 19 days and a maximum of 48 days after maturity. The females lived for a longer period than the males. The longevity of these individuals as adults was undoubtedly influenced by the unnatural conditions under which they were reared to maturity.

LONGEVITY OF ADULTS COLLECTED IN FIELD.

In a series of 93 life-history cages, each containing a pair of adults of *Chlorochroa sayi* collected in the field, the females lived a maximum of 78 days with an average of 33 days and the males a maximum of 66 days with an average of 23. Under field conditions the adults undoubtedly live for three or four months, while the adults of the last two generations remain in a dormant condition in their hibernating quarters all winter.

DURATION OF LIFE WITHOUT FOOD.

The life of the adult is very short when deprived of food during its period of normal activity in summer temperatures. Five pairs of adults confined without food under a daily maximum temperature of 75° to 85° F. began dying on the second day and all were dead at the end of the fifth day. Under the same circumstances five pairs of adults kept under a daily maximum temperature 15° lower began dying on the fifth day and all were dead at the end of the ninth day. During hibernation the body of the adult contains much fatty tissue which apparently acts as a reserve food supply.

SEASONAL DEVELOPMENT.

SEASONAL HISTORY.

In the latitude of northeastern New Mexico the adults of *Chlorochroa sayi* emerge from hibernation during the first warm days of late April or early May. At this time the ovaries of the females contain fully developed eggs, and if mild weather conditions prevail these eggs are deposited within a few days on the underside of the rubbish or other material composing the hibernating quarters.

The resulting nymphs feed and develop upon the young sprouts of Russian thistle or other plants which have developed early in the season under the protection of the accumulated rubbish. Upon reaching maturity, about the last week in June, the adults of this first generation and the survivors of the overwintering brood migrate to the fields of grain and feed upon the tender stems and developing heads until the grain ripens. It is during this period that most of the economic loss from the grain bug occurs. The females of this generation usually deposit their eggs on the underside of rubbish in the field, or on Russian thistle growing along the ditches, fence rows, or waste areas. Occasionally eggs are deposited on different parts of the host plant, notably the awns or beards of the head, but as a rule the female seems to prefer the underside of some object near the ground. The newly hatched nymphs from these eggs have not been observed to feed upon the cultivated crops, but apparently depend upon weeds, especially Russian thistle, for their sustenance until reaching the third or fourth instar.

The second generation is completed about the same time that the majority of the grain crops are harvested, during the first week in August. The surviving adults and large nymphs of the first two generations then migrate to fields of late grain, milo maize, Sudan grass, volunteer grain, or other food plants which then are developing heads. If none of these crops is present, the insects confine their feeding to any of the native food plants growing in the vicinity.

The individuals of the third generation, progeny of these adults, feed on the late grain crops, or on their native food plants, and reach maturity about the middle of September.

A very large percentage of the third-generation females do not oviposit until the following spring, but during favorable seasons a few of the earliest maturing individuals of this generation sometimes deposit eggs from which adults of a partial fourth generation develop, although most of the nymphs do not reach maturity.

With the advent of cold weather, in October or November, the surviving adults of the later generations seek hibernating quarters for the winter. Many nymphs in all stages of development also enter hibernation at this time but do not survive the winter.

SUMMARY OF SEASONAL HISTORY.

Hibernating adults deposit eggs during late April or early May.

First-generation nymphs feed on native plants and develop to maturity in late June. Adults migrate to grain fields and feed on developing heads.

Second-generation nymphs feed on native plants or grain heads and develop to maturity in late August. Adults migrate to fields of late grain or feed on native plants.

Third-generation nymphs feed as in the preceding generation and develop to maturity by the middle of September. Adults feed mostly on native plants.

A partial fourth generation develops on native plants and matures just before the advent of cold weather.

Adults of the second, third, and fourth generations enter hibernation during late October or early November. Nymphs enter hibernation but do not survive the winter.

NUMBER OF GENERATIONS.

In the section where these observations were made there are three distinct generations each year and sometimes a partial fourth generation. The broods overlap considerably and all stages of the insect may be found in the field from the middle of May until the species enters its hibernation quarters in October or November.

SEASONAL ABUNDANCE.

The adults of the grain bug are very numerous locally during the time of their emergence from hibernation in April and May. In one instance 30 adults were found under a single "cow chip" about 6 inches square; and a total of 175 adults were found under the dead weeds along a 20-foot space of an irrigation ditch. The period of greatest abundance occurs, however, after the development of the second generation in late June and during July. At this time many

fields of small grain have been observed in which the adults and nymphs averaged 4 or 5 to each head of grain. On several occasions a quart of the insects was swept within a space of five minutes. After the middle of July the numbers of each succeeding generation are greatly reduced by the activities of parasites and predacious enemies until at the end of the season it is sometimes very difficult to find specimens of the insects, or their eggs, in fields where they were formerly abundant.

HABITS OF NYMPHS.

GREGARIOUSNESS AND POWERS OF LOCOMOTION.

During the first instar the young nymphs are gregarious in habit and seldom leave the proximity of their parent egg cluster. Soon after the second instar is reached they may wander away singly in search of food, but usually are found feeding very close together. During the third and succeeding instars the nymphs become more solitary in habit, but if the food supply is abundant the entire progeny of one egg cluster may reach maturity within a few feet from the place of their incubation, and under exceptional circumstances they sometimes complete their development on the same plant. The nymphs are rather slow of movement and they lack the power of flight, but in cases of necessity the larger nymphs may crawl several hundred feet in search of food.

FEEDING.

The nymphs when feeding assume a position with the legs strongly braced against the plant, the head upward or downward. The setæ of the mouth parts are inserted at right angles to the body and the liquid contents of the host are removed by suction. In the case of small grains the nymphs remove the entire contents of each kernel through a single puncture, but when feeding on tender stems several punctures are made within short distances of each other. Apparently the nymphs can not pierce any plant tissue after its epidermis has become hardened.

In the early spring the nymphs of all stages feed upon Russian thistle but later in the season a large percentage of the fourth and fifth instar nymphs feed, with the adults, on the tender stems and developing heads of grain. The larger nymphs have also been observed feeding on the tender stems and newly formed seeds of alfalfa, but experiments demonstrated that the species could not be reared from egg to adult on this plant. Throughout the season the young nymphs of the first three instars appear to confine their attention almost exclusively to Russian thistle, and when other food plants are lacking the nymphs of the last two instars feed upon this plant.

DAILY ACTIVITY.

In calm and fair weather the nymphs of *Chlorochroa sayi* are active and feeding (see Table V) during the period from about 8 a. m.[1] until the heat of the sun becomes oppressive an hour before noon. Then they seek the shelter of some object and remain quiet until the heat of the sun abates, resuming their activity and feeding from about 2 p. m. until the atmosphere cools in the late afternoon. During the night, and the cooler periods at the beginning and end of each day, the nymphs remain inactive and generally seek some protected location. The same is true during periods of high winds or rainy weather.

TABLE V.—*Daily activity and feeding habits of nymphs of Chlorochroa sayi, July 15, 1916.*

Time.	Temperature.	Weather.	Observation.
A. M.	° *F.*		
4	63	Cloudy	Resting.
4.30	62		
5	62	Sunrise	
5.30	64	Cloudy	
6	69		
6.30	69	Partly cloudy	
7	72	Cloudy	
7.30	73		
8	74	Fair	Feeding.
8.30	76		
9	78		
9.30	80		
10	82		
10.30	83		
11	86		
11.30	87		
M.			
12	88		Resting.
P. M.			
12.30	91	Partly cloudy	
1	90	Cloudy	
1.30	93		
2	94	Quite cloudy	Feeding.
2.30	97		
3	90		
3.30	88		
4	88		
4.30	83		
5	82		
5.30	80	Less cloudy	Resting.
6	80		
6.30	80		
7	79		
7.30	77	Quite cloudy	
8	76		
9	73		

In discussing the feeding and activity of the nymphs, it should be understood that in the high altitudes of northeastern New Mexico the nights are very cool, even during the summer months, while high temperatures are recorded at midday.

The inactivity of the nymphs during certain periods, together with their habit of dropping to the ground and feigning death when approached, frequently leads many unobserving owners of damaged

[1] All references to clock time refer to "Standard time."

grain fields to underestimate the numbers of this species present, and very often the resulting damage is attributed to other causes.

HIBERNATION.

Although large numbers of nymphs enter hibernation quarters with the adults, they soon perish and in no instance have they been observed to survive the winter.

HABITS OF ADULTS.

COPULATION.

The adults of *Chlorochroa sayi* are found in copulation on the food plants, under rubbish, or around the bases of plants at all times of the day and night. The mating pairs face in opposite directions and the length of copulation varies from a few minutes to several hours. In one life-history cage a pair was observed in copulation for two entire days and it is probable that they had continued in this position throughout the intervening night. On several occasions, when observed in copulation on their food plant, either one or both of the sexes continued to feed during the act.

OVIPOSITION.

Oviposition occurs at any time of the day or night whenever the female happens to be resting or feeding. When ovipositing the legs are strongly braced and the abdomen is inclined at an angle, nearly touching the object on which the eggs are deposited. As each egg is forced through the ovipositor, the tip of the abdomen bends and deposits the egg in its appointed position. Normally the eggs in the lower end of a cluster are deposited first and with these as a foundation the succeeding eggs are added in transverse rows. (See fig. 3.) The intervals between the deposition of individual eggs in a cluster average about one minute, so that the total time required for oviposition depends upon the size of the egg cluster.

LOCATION OF THE EGG CLUSTERS.

The egg clusters of *Chlorochroa sayi* are found in a great variety of locations, but generally are placed on the lower side of some portion of the food plant or underneath some object in the vicinity. The adults emerging from hibernation deposit their eggs on the rubbish or dead plants comprising the hibernating quarters, but the adults of the succeeding generations generally select the living food plant, or its close vicinity, for egg deposition. On different occasions egg clusters have been found on various parts of the food plant, including the awn or "beard," the edges of the leaves, the head of beardless varieties, the upper and lower sides of the leaves, and the stem. Other locations selected for egg deposition were the lower side of "cow chips," clods of earth, stones, and tin cans, and the wire and posts of fences. On one occasion an egg cluster was found super-

imposed on a cylindrical cluster of eggs of the New Mexico range caterpillar (*Hemileuca oliviae* Ckll.) that had been deposited around a sunflower stem.

NUMBER OF EGGS IN EACH CLUSTER AND THEIR DISPOSITION.

Counts were made of 185 typical egg clusters collected in the field during 1915 and 1916. The number of eggs in individual clusters varied from 13 to 43, the average being about 26. The smallest egg cluster consisted of 9 eggs and the largest, apparently deposited by a single female, consisted of 75 eggs. No uniformity was apparent in the number of eggs composing each cluster. This is a deviation from the published records, which indicate that in closely allied species there exists a uniformity in the number of eggs in each cluster.

The eggs are deposited with considerable regularity in two or four parallel rows, each egg being placed in the alternate space between the eggs of the adjoining row (see fig. 3), and each row consisting of from 7 to 20 eggs. This tendency is particularly marked when plant stems or the awns of grain heads are selected for egg deposition. Frequently when eggs are deposited on the broad surface of an object the formation of the cluster is very irregular.

NUMBER OF EGGS DEPOSITED BY EACH FEMALE.

The females normally do not deposit their full complement of eggs at one time or in a single cluster. Twenty-one newly matured females collected in the field early in the season and placed in confinement deposited a maximum of 107 and a minimum of 9 eggs, the average being 54 eggs from each female. These eggs were deposited in from 1 to 10 clusters over periods extending from 1 to 16 days. (See Table VI.)

TABLE VI.—*Oviposition habits of confined females of Chlorochroa sayi.*

Female No.	Total number of eggs.	Number of separate clusters.	Number of eggs in each cluster.	Average number of eggs in each cluster.	Days between first and last oviposition.
1	91	5	53-3-7-14-14	18.1	16
2	56	1	56	56	.....
3	32	1	32	32	.....
5	60	6	3-4-6-44-1-2	10	5
9	62	3	59-1-2	20.2	1
10	43	2	4-39	21.5	1
12	107	5	56-30-11-4-6	21.2	10
16	11	2	8-3	5.5	2
17	16	1	16	16	.....
18	58	5	43-2-4-7-2	11.3	6
19	55	3	32-19-4	18	3
20	56	2	28-28	28	11
21	53	2	40-13	26.5	3
22	9	3	3-3-3	3	4
23	67	2	34-33	33.5	2
24	97	4	46-13-12-26	24.2	13
25	43	3	2-26-15	14.3	3
26	61	6	16-9-33-1-1-1	10.1	11
27	43	1	43	43	.....
28	71	2	60-11	35.5	9
30	43	10	31-2-1-1-1-1-1-1-2-2	4.3	2

On May 10, 1916, 25 females were collected from winter quarters and dissected for egg counts. The maximum number of eggs per female was 56, the minimum 16, and the average 37. The ovaries of each female also contained many eggs which had not yet reached their full development.

DURATION OF FERTILITY.

The duration in the fertility of females varies greatly with different individuals. In some instances the full complement of the female apparently is deposited at one time, and this fact accounts for the large number of eggs occasionally found in single clusters. Generally, however, the period of oviposition extends from a week to 20 or 30 days and during this time the female deposits from 2 to 6 or 7 small egg clusters. (See Tables VI and VII.) The latter is apparently the normal habit and explains the fact that the average egg cluster found in the field is smaller than the average capacity of normal females.

TABLE VII.—*Oviposition habits and duration of fertility of confined females of Chlorochroa sayi. Record started May 10, 1916.*

Female No.	Date eggs were deposited.																			
	May.																	June.		
	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3
1	....	3	....	....	....	....	....	53	....	....	7	....	....	....	14	....	....	14	....	....
2	....	....	....	....	....	....	....	....	56	....	....	....	....	....	....	....	....	....	....	....
3	....	....	....	....	....	....	....	....	....	32	....	....	....	....	....	....	....	....	....	....
5	....	....	....	....	....	....	....	....	3–4	....	....	6–44	....	1–2	....	....	....	....	....	....
9	....	....	....	....	....	....	....	....	....	1–2	59	....	....	....	....	....	....	....	....	....
10	....	....	....	....	....	....	....	....	....	....	4	39	....	....	....	....	....	....	....	....
12	....	....	....	....	....	....	....	....	....	56	....	....	....	....	....	....	....	....	30	11–4–6
16	....	....	....	....	....	....	....	....	....	....	....	....	8	....	....	3	....	....	....	....
17	....	....	....	....	....	....	....	....	16	....	....	....	....	....	....	....	....	....	....	....
18	....	....	....	....	....	....	....	....	....	43	....	....	2–4	....	....	7–2	....	....	....	....
19	....	....	....	....	....	....	....	....	....	32	....	19	4	....	....	....	....	....	....	....
20	28	....	....	....	....	....	....	....	....	....	....	28	....	....	....	....	....	....	....	....
21	....	....	....	....	....	....	40	....	....	13	....	....	....	....	....	....	....	....	....	....
22	....	....	....	....	....	....	....	....	3	....	....	3	3	....	....	....	....	....	....	....
23	....	....	....	....	....	....	....	....	....	34	....	33	....	....	....	....	....	....	....	....
24	46	....	....	....	....	....	....	....	13	....	....	12	26	....	....	....	....	....	....	....
25	....	....	....	....	....	....	....	....	....	2	26	....	15	....	....	....	....	....	....	....
26	16	....	....	....	....	....	....	....	9	33	1	1–1	....	....	....	....	....	....	....	....
27	....	....	....	....	....	....	....	....	43	....	....	....	....	....	....	....	....	....	....	....
28	....	....	....	....	....	....	....	....	60	....	....	....	....	....	....	....	....	....	....	11
30	....	....	....	....	....	....	....	....	1–1–1–1–1–1–1–2–31	....	....	2–2	....	....	....	....	....	....	....	....

The ovaries of females dissected late in the autumn or in early winter contain no eggs, but the abdomen is filled with a large amount of fatty tissue. Fertilization is probably accomplished during the last stages of hibernation in the very early spring and eggs develop within a short time. The ovaries of 25 females taken from hibernation in March were found to contain an average of 37 eggs and many additional immature eggs were present.

DAILY RATE OF OVIPOSITION.

The daily rate of oviposition varies considerably with individual females of the same age confined in life-history cages under identical conditions of food and environment.

Normally several days elapse between the deposition of each egg cluster, but occasionally a female deposits several small egg clusters on the same day, and frequently one or more egg clusters are deposited by the same female on successive days. (See Table VII.)

RELATION OF TEMPERATURE TO OVIPOSITION.

The amount of oviposition in the field is not noticeably affected by the ordinary ranges of summer temperatures, because many of the egg clusters are deposited by the females when they are in hiding during the cool periods of the day or during inclement weather. Probably, however, the greater percentage of the eggs is deposited during the warmer parts of clear days when the females are actively feeding.

FEEDING.

PARTS OF PLANTS PREFERRED.

The grain bug exhibits a marked preference for the juices of the seeds and fruits of its food plants and apparently feeds upon the tender stems and leaves only when more favored portions of the plants can not be obtained.

In grain fields the feeding is confined to medium sized and rapidly growing heads of immature seed. After the grain reaches the "dough" stage the insect ceases to feed upon it. Whether it does so because it prefers other food, or because the hardening of the glume containing the seed prevents the entrance of the setæ which constitute its piercing mouth parts, is not known.

METHOD OF ATTACK.

The adults attack and damage their food plants in much the same manner as has been previously described for the nymphs. The selected portion of the plant is pierced and its liquid contents removed by suction. The adults are very active in searching for the fruit or seeds of their food plants, and the total amount of damage caused by the insect in this stage is much greater than during the nymphal period.

CONSPICUOUS APPEARANCE WHEN FEEDING OR RESTING.

The grain bug adults are very conspicuous objects in the field, owing to their large size and tendency to seek the upper part of each plant, when feeding or resting on the grain heads. On clear days

the sunlight is reflected from the dorsal surfaces of the insects and adds to their conspicuous appearance. At this time at least 95 per cent of the adults present in the vicinity may be seen without moving any part of the plants. When disturbed, however, most of the adults immediately drop to the ground and seek cover.

ODOR AND EXCREMENT.

The characteristic odor of the adults and nymphs is not generally noticeable in the field even when the insects are present in large numbers. During thrashing operations, however, many farmers have reported that the odor given off by the grain bug was so noticeable as to cause much discomfiture to the workers. This was probably due to the fact that large numbers of the insects had concentrated about the grain shocks and had given off the offensive odor when disturbed. In life-history cages this offensive odor is not noticeable unless the insects are roughly handled.

The excrement of *Chlorochroa sayi* is a yellow-green fluid and is commonly found on the leaves or stems of the host plant. It varies in size from mere specks deposited by the young nymphs to circular masses 5 millimeters in diameter deposited by the adults.

DAILY ACTIVITY.

During the calm, pleasant weather of the summer months the adults of *Chlorochroa sayi* are active and feeding throughout the greater part of the day and night. They are not affected by the excessive heat of midday, as is true of the nymphs, but are more active and do most of their feeding while high temperatures prevail. (See Table VIII.) During periods of high winds, rain, or hail storms and nightly temperatures below 60°, the insects cease their activities and seek shelter, generally under some object on the ground or around the bases of their food plants.

TABLE VIII.—*Daily activity and feeding habits of adults of Chlorochroa sayi, July 15, 1916.*

Hour.	Wire cage 3 by 3 by 3 feet over wheat plot—2 male and 4 female adults.			
	Temperature.		Weather conditions.	Observation on activity.
	Shade.	Sun.		
A. M.	*°F.*	*°F.*		
4	63	.....	Cloudy	5 on heads in same position as at 9 p. m. last night; at least 2 have setæ inserted into grain head.
4.30	62	.....		Do.
5	62	.....	Sunrise; cloudy	4 resting.
5.30	64	.....	Cloudy	4 resting.
6	69	.....		2 resting.
6.30	69	.....	Partly cloudy	3 resting.
7	72	.....	Cloudy	Do.
7.30	73	.....		3 resting and feeding.

TABLE VIII.—*Daily activity and feeding habits of adults of Chlorochroa sayi, July 15, 1916*—Continued.

Hour.	Wire cage 3 by 3 by 3 feet over wheat plot—2 male and 4 female adults.			
	Temperature.		Weather conditions.	Observation on activity.
	Shade.	Sun.		
A. M.	°*F.*	°*F.*		
8	74	.....	Clear	2 feeding.
8.30	76	.....		3 feeding.
9	78	106		2 feeding.
9.30	80	114		Do.
10	82	118	Clear; wind rising	None feeding.
10.30	83	116	Clear	2 feeding.
11	86	104		3 feeding.
11.30	87	114	Clear; slight wind	Do.
M. 12	88	117		4 feeding.
P. M. 12.30	91	111	Partly cloudy; slight wind	Do.
1	90	114	Partly cloudy; no wind	Do.
1.30	93	107		5 feeding.
2	94	104	Cloudy	Do.
2.30	97	102		Do.
3	90	94		Do.
3.30	88	90		3 feeding.
4	88	88	Cloudy; slight wind	Do.
4.30	83	84		4 feeding.
5	82	82	Clearing; less wind	5 feeding.
5.30	80	87		4 feeding.
6	80	80	Clearing; no wind	Do.
6.30	80	.....		5 feeding.
7	79	.....	Clear; no wind	5 feeding and resting.
7.30	77	.....		Do.
8	76	.....		Do.
9	73	.....		Do.

Observations made at various times during the night indicate that the adults continue feeding after the daylight hours, providing that the temperature remains high enough for them to continue their activities.

PREDACIOUS AND CANNIBALISTIC HABITS.

In life-history cages the grain-bug adults frequently fed upon the contents of their own eggs. Under these same conditions the adults also fed upon the dead bodies of their companions and upon the issuing dipterous parasite larvæ. Apparently these predacious and cannibalistic habits are abnormal, as no observations of a similar character were made in the field, where on all occasions the nymphs and adults were observed to feed exclusively upon plants.

GREGARIOUSNESS.

The grain bug exhibits a marked degree of gregariousness in hibernation and to a more limited extent during its period of activity in the field. In May, 1916, a total of 30 hibernating adults were found under one "cow chip" about 6 inches square, and in the same vicinity 175 adults were collected from underneath the rubbish along a 20-foot space in an irrigation ditch. When feeding in the field they appear to prefer certain food plants to the exclusion of others of the same kind and in the same stage of development. This characteristic fre-

quently results in the concentration of 6 or 8 individuals on one grain head while similar plants in the vicinity receive but slight attention from the species. When large numbers of the insects are present in fields of wide area the adults appear to concentrate in certain portions of the field and change their location as the food supply becomes exhausted.

It is problematical whether this gregarious habit exhibited by the grain bug is a result of an attraction between the individuals or is largely stimulated by the presence of attractive food during its period of feeding and by superior facilities for protection during its inactive periods.

FLIGHT.

Generally the adults are very sluggish flyers and their flight is limited to a short distance. When disturbed they habitually drop to the ground for the purpose of seeking concealment without attempting flight. Under special conditions, however, the adults are capable of long and sustained flight. On June 30, 1916, large numbers of the adults were present on a small plot of wheat growing in the insectary grounds at Maxwell. The day was very warm, with no wind, and at this time when disturbed the adults took to flight and gradually ascended to a height of from 10 to 30 feet in the air, from this altitude maintaining a straight course as far as the eye could follow. Similar observations have been made in the field from time to time, and it is probable that these migrations generally are traceable to the need of a fresh food supply.

The adults have not been observed in flight during windy days, but the fact that they commonly migrate to the leeward side of the field at these times would indicate that their general line of flight was in the same direction as the prevailing wind.

On October 2, 1916, during a windy period, large numbers of adults were found feeding on the Russian thistle growing in the northeast corner of an abandoned wheat field. The wind was from the southwest, and although the adults were found in small numbers throughout the field, most of them apparently had been driven to their present location by the prevailing wind.

HIBERNATION.

The grain bug hibernates exclusively in the adult stage. No immature forms have been observed to survive the winter, although many of the larger nymphs enter hibernation with the adults and live for a short time.

LOCATION OF HIBERNATING QUARTERS.

In general, *Chlorochroa sayi* hibernates under and among dead weeds or rubbish, in crevices under the loose bark of trees or posts,

and around the bases of large uncut tufts of native grasses. The luxuriant growth of dead Russian thistle along irrigation ditch banks, fence rows, and roadsides, as well as piles of débris in the fields or pastures, affords ideal hibernating quarters for the insect. In cleaning out any of these habitats during the spring, it is not unusual to find scores of the adults concentrated within a very limited space. This circumstance at once suggests a simple and effective method for controlling the pest.

The hibernating adults apparently lack the power to burrow beneath the surface of the soil. Generally they are found directly underneath the material composing their hibernating quarters or in loose material on the surface of the ground.

MORTALITY DURING HIBERNATION.

In some localities there is a high percentage of adult mortality during hibernation. Frequently in the spring large numbers of dead individuals are found grouped together with only a very few living forms remaining. Under these circumstances it is probable that the hibernating quarters were exposed to unusually severe conditions and did not afford the contemplated protection from winter temperatures. It is also possible that parasites, predators, or fungous diseases occasionally may be responsible for the high rate of mortality.

Under more favorable conditions for hibernation it is not uncommon to find that among hundreds of adults at least 95 per cent have survived the winter.

Severe winters undoubtedly result in the death of a large percentage of hibernating adults and form one of the most important factors in restricting destructive outbreaks of the species.

CHANGE OF COLOR DURING HIBERNATION.

In hibernation the adults of *Chlorochroa sayi* change to a greenish-pink color, quite distinct from their normal summer appearance. This change is not evident in the autumn when the adults are seeking their winter quarters or in the spring directly after they have emerged from hibernation. Adults collected in the autumn and kept active throughout the winter in a stove-heated room assumed the same characteristic color as the inactive adults in outdoor hibernating quarters. The specimens reverted to their normal coloration in the spring. Possibly this change in the appearance of the species during the summer and winter seasons may serve as protective coloration.

The winter coloration persists in the pinned museum specimens of adults collected from hibernation.

NATURAL ENEMIES.

PARASITES.

During the course of the investigations in New Mexico one proctotrypid parasite, *Telenomus ashmeadi* Morrill, was reared from the eggs of *Chlorochroa sayi*, and two tachinid parasites, *Gymnosoma fuliginosa* Desv. and (*Ocyptera*) *Ocypterodes euchenor* Walk. were reared from the adults of the species.

PARASITES OF THE EGG.

The egg parasite *Telenomus ashmeadi* (fig. 11) constitutes one of the most effective natural agents in the control of *Chlorochroa sayi* and is very widely distributed throughout the area infested by the pest. During the latter part of July and the early part of August, in 1915, adult parasites emerged from about 60 per cent of the eggs collected in badly infested fields. In many egg clusters a parasite emerged from each and every egg. In all instances under observation it has been noted that nymphs rarely hatch from an egg cluster when any of the individual eggs produce parasites. Upon dissection these unhatched eggs generally are found to contain dead parasites or to be nearly devoid of contents, apparently the result of parasitism. It is evident from the foregoing that the percentage of eggs from which adult parasites emerge does not necessarily indicate the full total of parasitism in the field.

FIG. 11.—*Telenomus ashmeadi*, an egg parasite of the grain bug. Greatly enlarged. (Morrill.)

On July 27, 1916, a dozen reared parasites were confined in a glass vial with a freshly deposited egg cluster of *C. sayi*. Within two minutes the females began ovipositing. During this process the female stands on the two posterior pairs of legs with the body nearly vertical and inserts her short ovipositor into the egg, meanwhile bending the head and antennæ forward. They prefer to oviposit in the top of the egg or in the side of the egg near its top. On August 13 the adult parasites began emerging from this egg cluster, a total of 17 days being required to complete the life cycle of the parasite

in this instance. In a similar experiment started on August 17, 1915, the duration of the life cycle was 26 days.

The comparatively short life cycle of *T. ashmeadi* enables the species to complete several generations each year and greatly increases its value as a parasite.

PARASITES OF THE ADULT.

Field collections made from various and widely separated localities during 1915 and 1916 demonstrated that in some fields nearly 25 per cent of the adults and last-instar nymphs were parasitized by the tachinid fly *Gymnosoma fuliginosa.*

FIG. 12.—*Gymnosoma fuliginosa,* a fly parasite of the grain-bug adult. Much enlarged.

According to Morrill (5) the female of this species usually deposits her eggs near the margin of the body on the ventral prothoracic region of the adults and fifth-instar nymphs. The manner in which the resulting larva enters the body of its host has not been observed. The body contents are consumed within a short time and the fully developed parasite larva makes an exit through the anal opening of its host and enters the ground for pupation. The period of pupation for 24 individuals reared during the summer of 1916 varied from 6 to 15 days, the average period being 11.4 days.

The parasitized insect retains its activity and powers of destructiveness up to within a short time before the parasite is due to emerge. This characteristic detracts somewhat from the value of *G. fuliginosa* and renders it of less importance than the egg parasite

Telenomus ashmeadi in the natural control of *C. sayi.* Frequently death does not occur until several hours, or even days, after the parasite has left the body of its host, the host meanwhile remaining inactive.

Although eggs are deposited on the nymphs, no instances were observed in which the larvæ of *G. fuliginosa* completed their development and issued before the host reached its adult stage.

The seasonal history of *G. fuliginosa* corresponds very closely with that of *C. sayi* and there are the same number of generations annually. The adults are engaged actively in parasitizing *C. sayi* throughout

FIG. 13.—*Ocypterodes euchenor,* a fly parasite of the grain-bug adult. Much enlarged.

the period of activity of the host, extending from April to October or November. They are most numerous during the months of July and August, and at this time a dozen or more individuals have been collected by a few sweeps of the net in fields that were heavily infested with *C. sayi.*

The parasite hibernates, in some instances at least, as a larva within the body of its host. In February, 1916, during severe winter weather, 25 adults of *C. sayi* were collected from hibernation at French, N. Mex., and placed in a heated room. They became active within a few hours and 3 days later 2 larvæ of *G. fuliginosa* issued. These larvæ were placed in a pupating cage and the resulting adults emerged 16 days later. It is probable that the parasite also hibernates as a puparium

beneath the surface of the ground, as many individuals in this stage have been dug from the soil underneath the hibernating quarters early in the spring. This fact was not definitely established, however, owing to the difficulty encountered throughout the winter in examining the frozen soil of these locations.

Eight specimens of the tachinid *Ocypterodes euchenor* Walk. were reared from several hundred adults of *Chlorochroa sayi* kept in confinement during 1916. The species has been observed infrequently in the field and must be considered of only minor importance in the natural control of *C. sayi.* Its life cycle and habits, as far as observed, were very similar to those of *Gymnosoma fuliginosa.*

PREDACIOUS ENEMIES.

The offensive odor secreted by the scent glands of *Chlorochroa sayi* has been commonly supposed to protect them from the attacks of predatory enemies. While this odor may act as a repellent to some of its enemies, in the case of *C. sayi* the different stages of the insect are preyed upon by quite a variety of both vertebrate and invertebrate enemies. Considered individually these enemies are not of great importance in the control of the pest, but in the aggregate they undoubtedly exert considerable influence in the reduction of its numbers.

PREDATORY INSECTS.

The adults of the malachiid beetle *Collops bipunctatus* Say feed upon the eggs of *Chlorochroa sayi* in the field. This small beetle is very numerous in the grain fields of New Mexico and apparently is one of the most effective predatory enemies of the grain bug. In confinement a single adult of this species devoured in one day an egg cluster consisting of 10 eggs, consuming even the eggshells. The same individual, however, refused to feed upon small nymphs of *C. sayi.*

When confined in cages the adults of *C. sayi* frequently fed upon their own eggs, but this habit has not been observed in the field.

The adults of *Sinea spinipes* H. S. and of *Phymata erosa* Stål have been observed feeding upon the nymphs of the grain bug in the field.

BIRDS.

The Bureau of Biological Survey reports that *Chlorochroa sayi* has been found in the stomachs of the nighthawk (*Chordeiles virginianus*) and the meadowlark (*Sturnella neglecta*), and that individuals of other species of the same genus have been found in the stomachs of the bobwhite (*Colinus virginianus*), kingbird (*Tyrannus tyrannus*), Brewer blackbird (*Euphagus cyanocephalus*), Franklin gull (*Larus franklini*), and English sparrow (*Passer domesticus*).

MISCELLANEOUS ENEMIES.

The Rocky Mountain toad (*Bufo lentiginosus woodhousei*) has been recorded by the Biological Survey as feeding upon various species of Chlorochroa.

A half-grown chicken devoured 8 adults during a single day, when placed in a large outdoor cage with these insects. It has been commonly reported by farmers that a diet of grain bugs often kills barnyard fowls, but these reports have not been verified.

CONTROL METHODS.

DESTRUCTION OF HIBERNATING QUARTERS.

The obvious method for controlling the grain bug is the destruction of the adults when they are concentrated in their hibernating quarters. This is best accomplished in the late autumn, during the winter, or in the early spring by plowing under or burning all weeds and rubbish in and about cultivated fields. This applies particularly to the dead Russian thistle in abandoned fields and along irrigation ditches, check ridges, and fence rows; in fact, all locations where the accumulations of weeds or rubbish afford suitable hibernating quarters. Even in the large-scale farming operations which predominate throughout most of the territory infested by the insect, it is possible to carry out these measures of control as a good farming practice which contributes to the destruction of weeds and of various species of noxious insects. Much of the local infestation results from hibernating adults that wintered in the same field or its vicinity and which could have been destroyed by the farmer with an expenditure of very little additional labor. In many instances, however, the grain bug adults migrate from considerable distances and this circumstance necessitates a systematic clean-up community campaign in badly infested areas. Objections often are offered to control measures similar to the foregoing, because of the time and expense involved in their application, but it must be borne in mind that any extra efforts required to prevent insect depredations are repaid manyfold in the increased production of the crops. The measures recommended herein for the control of the grain bug should be included in good farm practice at any event and can be carried out during a time when farm labor and equipment ordinarily are idle.

TRAP CROPS.

Early in the season the immature stages of the first generation of the grain bug are concentrated on the tender plants of Russian thistle and other native plants growing in the waste areas of cultivated fields. At this time the multiplication of the species may be restricted greatly by spraying these areas with a strong insecticide or chemical, thus killing the insects and their obnoxious food plants in one operation.

HAND PICKING.

Hand picking of the grain bug adults and nymphs may possibly prove practical when valuable crops growing on small areas are attacked. These conditions often occur in the high-priced irrigation areas of the Southwest.

HOPPERDOZERS.

It has often been suggested that a hopperdozer might be employed to collect the adults and nymphs of the grain bug while they are feeding on the heads of the grain. An operation of this kind, however, would be complicated by the fact that the insects generally drop to the ground when closely approached. Then, too, at the time when most of the injury by the grain bug occurs the condition of the grain is such that the passage of any collecting machine would result in considerable damage to the crop.

A modification of the hopperdozer might be effective when the attacked crops are grown in hills or rows.

ASSOCIATED SPECIES OF PLANT BUGS.

A few nymphs and adults of *Thyanta custator* Fabr., *Thyanta rugulosa* (Say) Uhl., and several species of the genus Euschistus generally were found associated with *Chlorochroa sayi* in the field and closely resembled the latter in their life history and habits. None of these species was present in sufficient numbers to cause appreciable damage in the section of the country where these observations were made.

SUMMARY.

1. Since 1911 the grain bug (*Chlorochroa sayi* Stål) has become a serious enemy of wheat and other small grains in the intermountain and southwestern States.

2. The most important damage is caused by the insect piercing the newly formed heads of various cereals and removing the liquid contents, thus preventing the formation of the grain or greatly reducing its weight.

3. The reduction in yield from grain-bug attack varies from 10 to 50 per cent of the crop. In extreme cases the entire crop may be destroyed.

4. The cultivation of large areas formerly devoted to grazing eliminated the native food plants of the insect and caused it to attack cultivated plants.

5. This change to more succulent food plants, together with the superior facilities afforded for hibernation in the cultivated areas, resulted in an increase of the pest beyond its former abundance.

6. Wheat, barley, and rye are the preferred food plants among the cultivated crops. The species also feeds upon other cereals, and upon alfalfa, cotton, peas, beans, cabbage, tomato, and lettuce, in addition to many native plants.

7. The first recorded damage occurred in 1903, and since that time destructive outbreaks have been reported from most of the States west of the Great Plains area.

8. Weather influences and the work of parasites generally restrict destructive outbreaks in each locality to periodic intervals of two or three years.

9. Adults emerge from hibernation in the early spring and deposit eggs on the material composing the hibernating quarters. The resulting nymphs feed upon tender plants growing in the vicinity.

10. Upon reaching maturity the adults migrate to grain fields and feed upon the developing heads.

11. There are three distinct generations and sometimes a partial fourth generation annually. About 50 days are required to complete the life cycle of each generation.

12. After midsummer the numbers of the insects are greatly reduced by an egg parasite, *Telenomus ashmeadi*, and by two species of tachinid parasites, *Gymnosoma fuliginosa* and *Ocypterodes euchenor*, which parasitize the adults. Several kinds of predacious enemies contribute to the same result.

13. Hibernation occurs in the adult stage under weeds or rubbish. No nymphs or eggs survive the winter.

14. Severe winters result in the death of a large percentage of hibernating adults and constitute one of the most important factors in restricting destructive outbreaks of the species. During normal winters at least 95 per cent of the adults survive when hibernating in protected locations.

15. The most effective and practical method of control is the destruction of the adults while they are concentrated in their winter quarters. This is best accomplished by plowing under, or burning, all rubbish and weeds, particularly Russian thistle, in and about cultivated fields. These control measures should be included as a part of the regular farm practice and any special work required may be carried on during the inactive season at a time when the farm labor and equipment ordinarily are idle.

16. Trap crops, hand picking, and hopperdozers might prove practical in the control of the insect under special conditions.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 780

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

Washington, D. C. PROFESSIONAL PAPER June 12, 1919

NOSEMA-DISEASE.

By G. F. White,
Specialist in Insect Diseases.

CONTENTS.

INTRODUCTION.

Nosema-disease is an infectious disease of adult honeybees. It causes the death of many individual bees, tending thereby to weaken the colonies infected. Many colonies die of the disease, but the percentage of deaths is comparatively small and entire apiaries are rarely, if ever, destroyed by it. It is not to be considered, therefore, as a particularly serious disorder. This is shown by the results recorded throughout the present paper. It is to be thought of rather as a disease the losses from which are less to the infected apiary than the losses from either of the foulbroods, although greater than those

from sacbrood. The disease is one, however, of considerable economic importance.

The fact that Nosema-disease is not a new disease deserves emphasis. The knowledge of the disease and its name only are of recent origin. Nosema-disease, like the brood diseases, has probably existed among bees longer than history records the keeping of bees by man. Since the disease is not a new one, fear regarding additional losses from it would not be justified. On the other hand, as we know of the disorder, we may entertain the hope that the losses due to it may now be lessened.

Until 1909 the existence of Nosema infection among bees was not generally known to beekeepers, although it had been studied somewhat by Dönhoff (1857) about a half century earlier. Zander began his studies a decade ago and since the appearance of his first paper (1909) a number of investigators have made studies on the disorder. In the papers which have been written concerning the infection, widely differing views regarding certain points have been expressed. To discuss these different views would be to go beyond the scope of the present bulletin.

The writer began the study of Nosema infection in 1910 following the demonstration by him that the disorder exists in the United States. In pursuing these investigations the object has been not to devise a treatment for the disease, but rather to ascertain such facts concerning the disorder that the beekeepers might be able to devise methods for its treatment with the assurance that they would be not only efficient but also economical. While there is yet much to be learned about the disease, this object has been fairly well attained. Relations which the results obtained bear to practical apiculture should be borne in mind, therefore, in reading the paper.

During the studies the effect of the disease on colonies and on apiaries, the transmission of the disease, the resistance of the infecting germ to heat, drying, sunlight, fermentation, putrefaction, and disinfectants, and the effect of drugs on the disease are among the problems which have been considered.

An earlier paper (White, 1914) refers briefly to the nature of the results obtained from these studies. The present bulletin gives all the results obtained from them which are believed to be of direct practical value to the beekeeper or otherwise of particular interest to him. The nature of the bulletin is similar, therefore, to the one on sacbrood (White, 1917) recently published.[1]

[1] As in the sacbrood paper, so in the present one, technical discussions have been purposely avoided. The semitechnical points which could not well be omitted are briefly explained in the sacbrood paper. Unless the reader is familiar with the nature of such investigations, the sacbrood bulletin will probably be found helpful in following the present one.

NAME OF DISEASE.

About 60 years ago Dönhoff (1857, March) discovered small oval bodies upon examining microscopically the stomachs from adult bees which he supposed had died of exposure. He sent some of the bees to Leuckart, who after an examination of them expressed the belief that the oval bodies were the spores of a fungus ("Pilz"). The disorder was referred to by Dönhoff (1857, August) by the term "Pilzsucht" (fungous disease).

These observations apparently had been practically forgotten at the time Zander (1909) reported his studies on a disease of adult bees in which he found small oval bodies in the walls of stomachs taken from affected bees. These were in fact the parasites that cause the disease. To the germ Zander (1909) gave the name *Nosema apis* and for the disease he (1911) used the name "Nosemaseuche."

The disorder studied by Dönhoff and the one studied by Zander are almost without question one and the same condition. It will be noted that each of these men in referring to the disorder used a term containing a reference to the parasite considered by each, respectively, as being its cause. The term "Nosema-disease,"[1] which the writer (1914) has suggested as the common name[2] for the disease, is not a new one, it will be observed, but simply an English translation of the term "Nosema-seuche" used by Zander.

In Switzerland "Nosemakrankheit" (Nosema-disease) (Nussbaumer, 1912; Angst, 1913) is the term commonly used in referring to the disease. In Denmark Bahr (1915) used the term "Nosemasygdommen" (Nosema-disease).

The name "Nosema-disease" possesses certain features which commend it: (1) It is definite, as it can refer only to the disease caused by *Nosema apis*; (2) it suggests the nature of the disease by referring to its cause; (3) it is readily understood; and (4) it is not long.

Care should be observed that Nosema-disease is not confused with dysentery. Leuckart (1857, March) early raised the question regarding its relation to dysentery. The question was soon afterwards

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[1] It will be observed that there are two parts to the name and that the name of the disorder is not "Nosema," but "Nosema-disease." It is suggested, therefore, that the name be written, for the present at least, as a compound word. By so doing the difficulty which has been experienced by some will be avoided.

[2] While working on a disorder which had received the common name "Isle of Wight disease," Fantham and Porter (1911), in England, encountered a protozoan parasite belonging to the group Microsporidia which they identified as being *Nosema apis*. In selecting a technical name for the disorder caused by the parasite they chose the term "Microsporidiosis," derived, as will be observed, from the group name Microsporidia, under which the parasite is classified. The name is, therefore, an appropriate one. The term has received some criticism on account of its length and possibly on account of its not being readily understood.

As the parasite is now believed to belong to the genus "Nosema," the writer begs to suggest that as a technical name for the disorder the term "nosemosis" would have some arguments in its favor. This is not to be interpreted as proposing a substitute for the earlier term "Microsporidiosis." It is meant, rather, as an explanation of it.

taken up by Brotbeck (1857). Zander (1909) in his first paper referred to Nosema infection as a (malignant) dysentery. Other discussions have appeared from time to time in regard to such relationship (Maassen and Nithack, 1910; Beuhne, 1911; Maassen, 1911).

In fact the two disorders are very different and should be considered, for the present at least, as having no direct relation to each other. As both conditions are widely distributed and occur most frequently in the spring of the year, it is to be expected that not infrequently both of them may be encountered together in the same colony.

Efforts have been made to determine the name by which Nosema-disease has been known to beekeepers in the past. In these studies it was found (p. 16) that the highest percentage of Nosema-infected bees occurred in weak colonies. Consequently in asking beekeepers for samples bees from weak colonies were requested. In response to the request made approximately 150 samples were received. Fully half of these contained *Nosema apis*. Nine representative beekeepers located in different sections of the country that sent Nosema-infected bees were asked concerning the name by which the colonies showing the weakened condition were known. Three replied spring dwindling; two, not spring dwindling; two, weak colonies; one, bad queen; and one, "Don't know." None suggested paralysis and none dysentery.

In reply to requests for bees from colonies showing spring dwindling 38 samples were received from 14 beekeepers located in different sections of the country. Out of the 38 samples 15 upon examination revealed the presence of *Nosema apis*. From these 15 samples 314 bees were examined, of which 70 were found to be Nosema-infected.

Samples have been received from five beekeepers who diagnosed the condition in the colonies from which the bees were taken as paralysis. *Nosema apis* was not found in any of them.

The facts indicate, it would seem, that beekeepers had not learned to recognize the disease produced by *Nosema apis* by any one name.

DIGESTIVE TRACT OF ADULT BEES.

In Nosema infection the parasite *Nosema apis* enters, infects, and leaves the bee by way of the digestive tract. It is well, therefore, to know something of the location, arrangement, appearance, and structure of the organs of the alimentary canal of the healthy adult bee in order that the disease when encountered may be recognized and more fully understood.

The following description is an abbreviation of a general survey of the alimentary tract by Snodgrass (1910). The part of the alimentary canal (fig. 1) immediately following the mouth forms an enlargement called the pharynx (*Phy*). Succeeding this is the œsophagus (Œ),

a slender tube traversing the entire thorax. In the anterior part of the abdomen the œsophagus expands into a large thin-walled sac which is known as the honey stomach (*HS*); next is the short neck-like portion, the proventriculus (*Pvent*); then comes the large U-shaped portion, the stomach or ventriculus (*Vent*), an organ with thick walls and many annular constrictions. Following the stomach is the short, narrow and coiled, small intestine (*SInt*) having a circle of about one hundred long, greatly coiled, blind, thread-like tubes opening into its anterior end. These tubes are the Malpighian tubules (*Mal*). Following the small intestine is the large intestine or rectum (*Rect*). When bees have been confined for some time this latter portion of the canal is found distended with material to be voided.

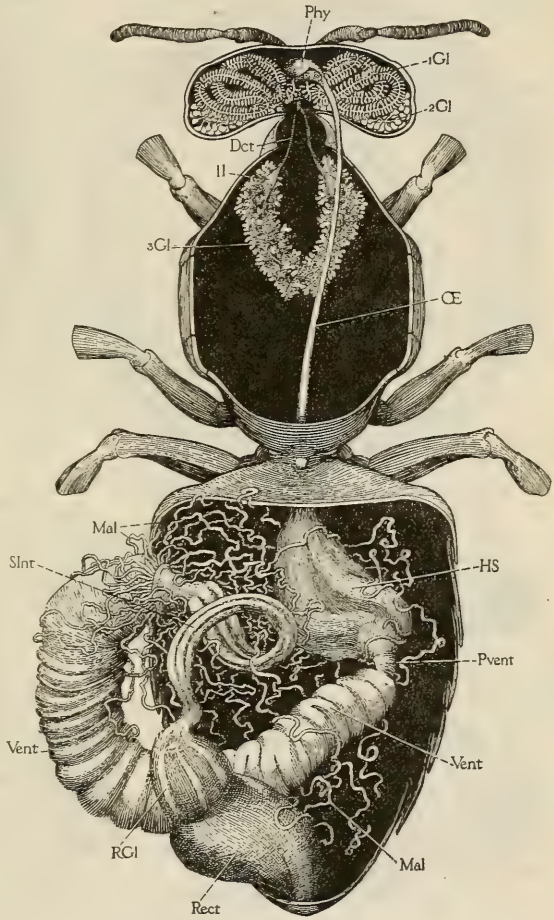


FIG. 1.—Alimentary canal of worker bee: Pharynx (*Phy*), œsophagus (*Œ*), honey stomach (*HS*), proventriculus (*Pvent*), stomach or ventriculus (*Vent*), small intestine (*SInt*), and large intestine or rectum (*Rect*), rectal glands (*RGl*), Malpighian tubules (*Mal*). Salivary glands of head (*2Gl*) and thorax (*3Gl*), and pharyngeal glands (*1Gl*) are also shown. (Snodgrass.)

Since the stomach is always invaded by the parasite in Nosema-disease, and the Malpighian tubules occasionally are, a further description of the structure of these organs seems warranted.

The stomach (fig. 1, *Vent*) is a relatively thick-walled organ lying U-shaped within the abdomen. When removed and straightened it is seen to be in general cylindrical but somewhat spindle-shaped in form. (Pl. I.) Circular constrictions present give to it a segmented appearance. The number and distinctness of these transverse markings vary somewhat. The size of the organ and its color vary also. The color varies within wide limits, being usually some shade of

brown. It may be quite light, approaching a yellow, or it may be dark, approaching the red observed in the flesh of the ox. Stomachs of the lighter shades especially are translucent.

The rather thick walls of the stomach (fig. 2) consist of an inner epithelial and an outer muscular portion. Between these is the

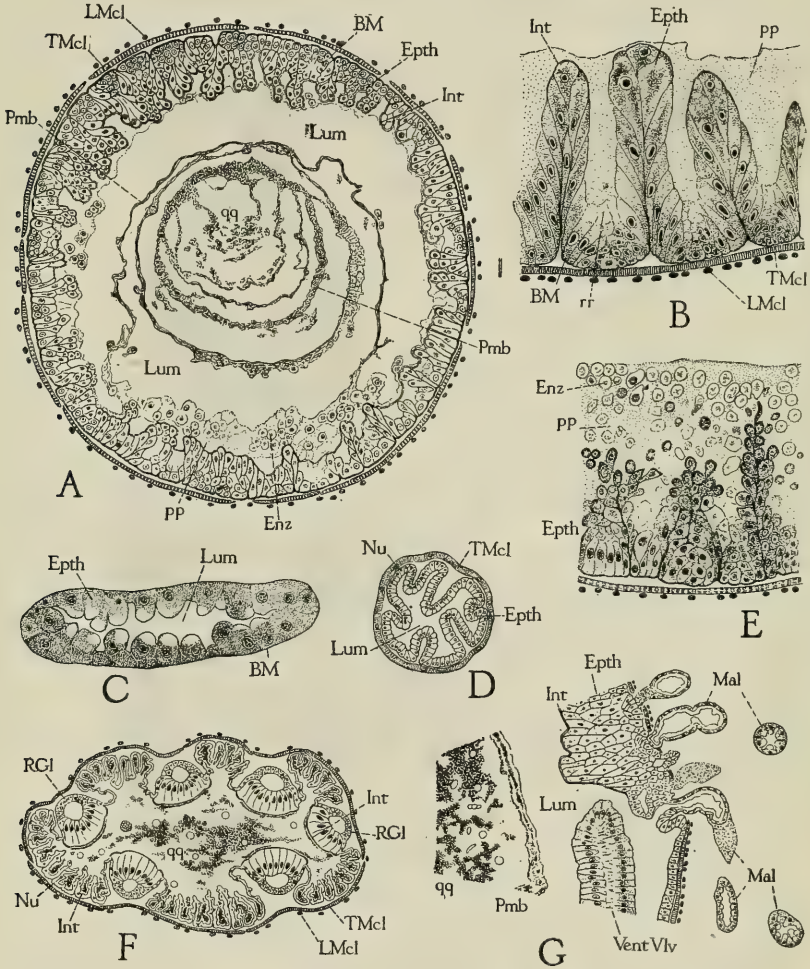


FIG. 2.—Microscopic anatomy of alimentary canal of worker bee: *A*, cross section of stomach showing peritrophic membranes (*Pmb*); *B*, wall of stomach, more highly magnified, showing epithelial layer (*Epth*), basement membrane (*BM*), and muscular portion; *C*, section of Malpighian tubule showing epithelium (*Epth*) and basement membrane (*BM*); *D*, cross section of small intestine. This portion of the canal, the rectum, and the œsophagus have a heavily chitinized intima. (Snodgrass.)

basement membrane. Both surfaces of the epithelial layer are irregular. This consists of epithelial cells (*Epth*) varying in size and outline. Closely associated with the outer surface of the epithelial layer is the basement membrane (*BM*). In connection with its inner surface is the more or less indefinite intima (*Int*) which possibly

bears some relation to the peritrophic membranes (*Pmb*). Outside the basement membrane is the muscular portion of the stomach wall consisting of three (White, 1918) muscular layers (Pl. II, D; and Pl. III, L). The outer and inner ones are made up of longitudinal and the middle one of circular fibers (fig. 3). Each layer is made up of a single layer of branched fibers.

Digestion and absorption, comparable to some extent to those obtaining in the human stomach, are functions which have been attributed to the stomach of the bee.

The Malpighian tubules (fig. 2, G *Mal*) empty into the alimentary tract at or very near the juncture of the stomach and small intestine. Microscopically their structure is seen to consist of a single layer of

FIG. 3.—Longitudinal section of stomach of honeybee showing infection with *Nosema apis*: *ep*, Epithelial portion, containing the spores of the parasite stained black. (The younger parasites, not differentiated so easily by staining, are not shown; they are found toward the base of the cells reaching the basement membrane (*BM*), but do not extend beyond it. Younger spores sometimes show an unstained area at one end and occasionally at both ends.) *m*, muscular portion of stomach wall showing an outer and an inner longitudinal muscular layer and a middle circular one. (Author's illustration.)

epithelial cells (fig. 2, C, *Epth*) and a basement membrane (*BM*), but no pronounced intima. The function attributed to these tubules is one comparable in a measure to that of the kidneys of the vertebrates.

CAUSE OF NOSEMA-DISEASE.

THE EXCITING CAUSE.

On December 4, 1856, Dönhoff (1857, August) inoculated a colony of bees with the oval bodies he had found in the stomachs of adult bees. The inoculation was made by feeding the colony the crushed stomachs of the infected bees in a honey suspension diluted with water. Upon examining stomachs from adult bees taken from the inoculated colony in eight days following the inoculation no spores were observed. In 11 days, however, they were found to be teeming with the parasites. A second colony was then similarly fed on Decem-

ber 16. On the twenty-ninth of the same month all of the bees examined from the colony were found to be infected. The results of these experiments strongly indicated that the disorder in which the oval bodies were found was an infectious one and that the bodies were parasites which bore a causal relation to the disease. Other studies made by Dönhoff (1857, September) indicated that the parasite was quite prevalent in Germany but that there were colonies apparently free from infection.

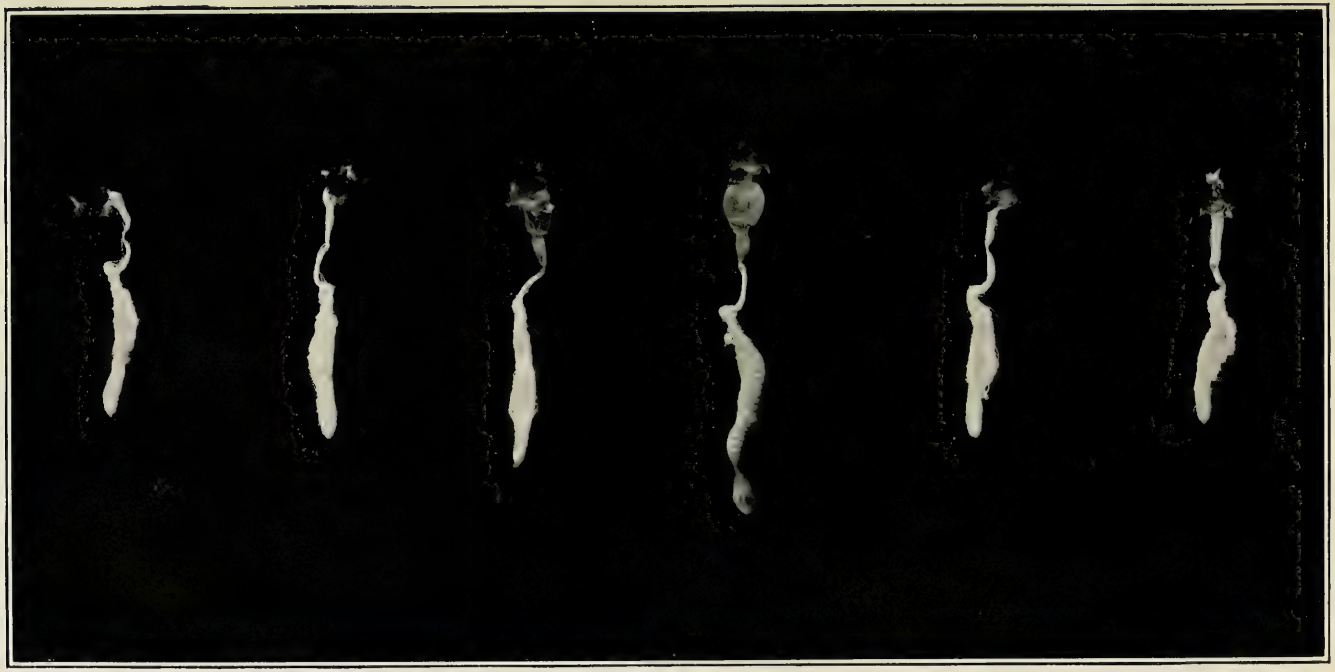
About 50 years later Zander (1909) inoculated colonies experimentally by feeding material containing the oval bodies he had encountered in his studies. In bees from the colonies inoculated he demonstrated that the oval bodies were in the walls of the stomach. This fact showed still more conclusively that there was an infectious disease of adult bees in which the oval bodies were parasites bearing a causal relationship to the disease.

The oval bodies studied by Zander and those studied by Dönhoff in all probability are the same. To Zander, however, is due the credit for having determined their true nature. Together with Döflein he (1909) classified the germ as a protozoan (a one-celled animal parasite) belonging to the group Microsporidia and to the genus Nosema. Zander gave the name *Nosema apis* to the species he found in the honeybee.

The parasite *Nosema apis* grows and multiplies for the most part in the epithelium of the stomach (fig. 3; Pls. II and III) of the adult bee. Occasionally, but rarely, it is found within the epithelial cells of the Malpighian tubules (Pls. II and III). When *Nosema apis* is encountered in making an examination for the parasite it is the spore form (fig. 4; Pl. III, G, H) that is most often encountered and most readily recognized. Viewed microscopically the spore in unstained preparations is seen to be a small, refractile, more or less oval body varying somewhat in size but measuring about 2/10,000 of an inch in length and about 1/10,000 of an inch in width. Its width seems, however, to be slightly greater than one-half its length.[1] The spore is surrounded by a somewhat resistant coat which tends to maintain for it a constant form. It is not, however, a rigid structure, since, when studied in fresh preparations, it will be seen to bend to and fro as it is carried along by a current under the cover glass.

The manner in which a bee becomes infected with *Nosema apis* is in general as follows: Spores which have left the body of an infected bee with the excrement are ingested by the healthy adult bee. The environment within the stomach of the bee is favorable for the

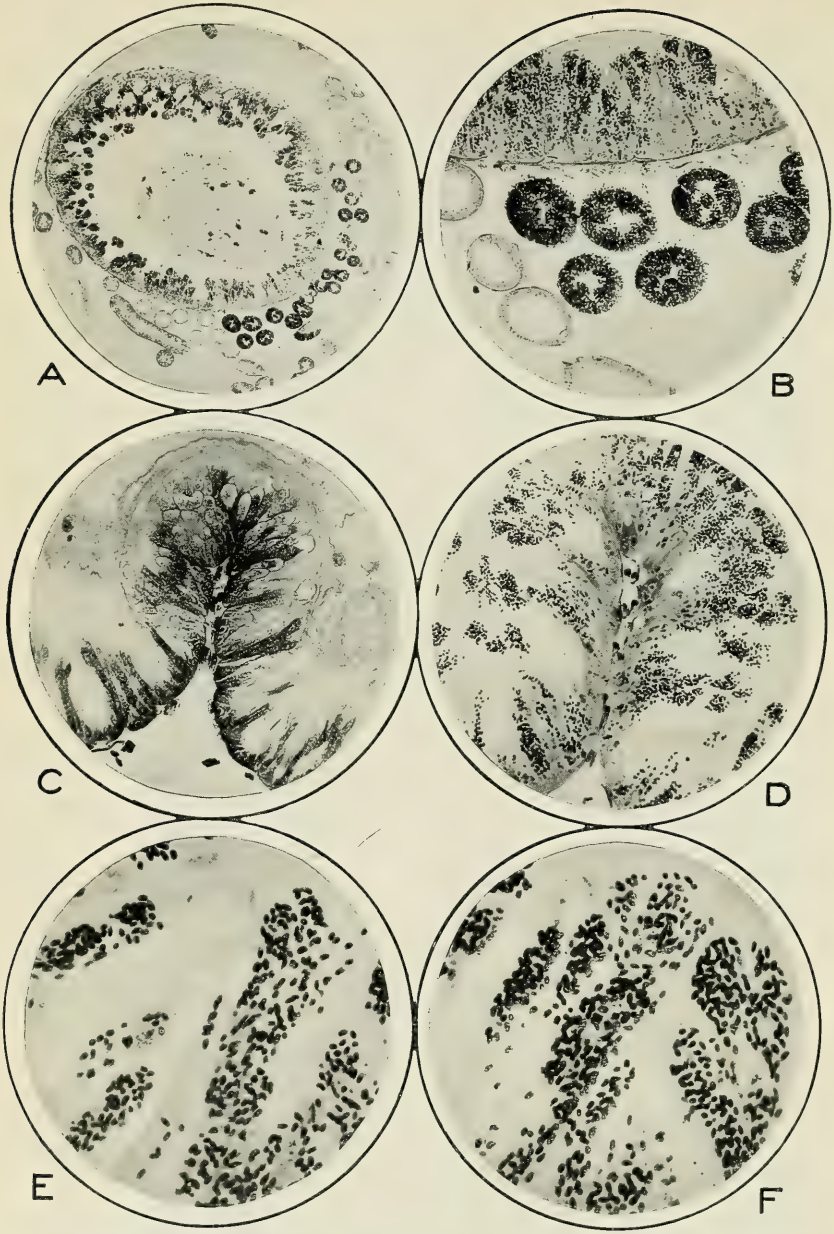
[1] Measurements were made of spores in smears stained with iron hematoxylin and of others in preparations made by an India-ink method. In making the latter preparations thin smears of the spore containing material were made and allowed to dry, and over these smears a thin film of undiluted India ink was spread. The average length of the spores measured in the stained preparations was 4.15 μ and the average breadth 2.06 μ; the average length in the India ink preparations was 4.46 μ and the average breadth 2.44 μ.



1 2 3 4 5 6

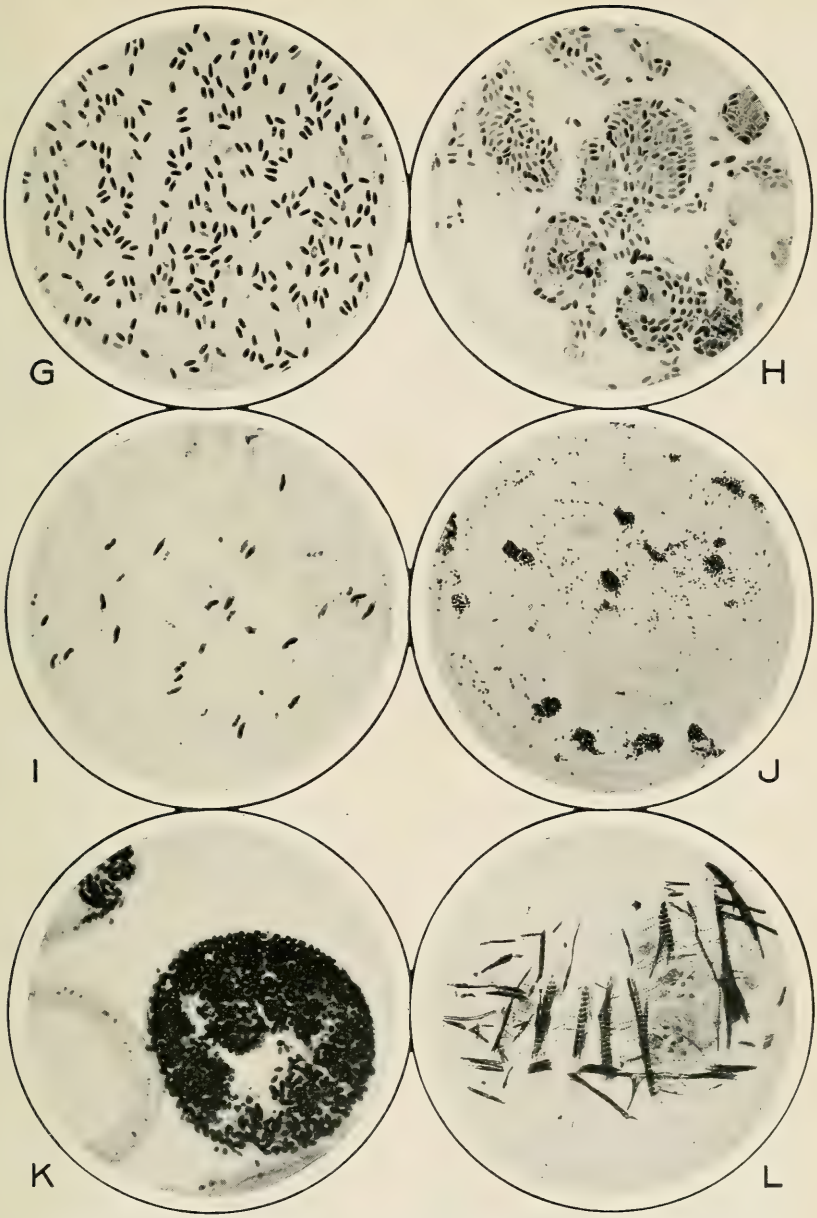
STOMACHS OF WORKER BEES REMOVED FOR EXAMINATION.

The tip of the abdomen, the large intestine, the small intestine, and, in one instance, the honey stomach also are shown. From left to right (1) a healthy stomach, (2) one recently Nosema-infected, (3) one infected for a longer period, and (4), (5), and (6) each respectively infected for a period longer than the one preceding it. (Original.)



PHOTOGRAPHS OF SECTIONS OF THE STOMACH OF THE HONEYBEE AS SEEN THROUGH THE MISCROSCOPE.

A, entire cross section of stomach (queen) and Malpighian tubules, showing infection of these organs with *Nosema apis; B*, a portion of *A* more highly magnified; *C*, a small portion of a longitudinal section of a stomach from a healthy bee; *D*, similar to *C*, but from a Nosema-infected bee; *E*, infected epithelium highly magnified, the disease as seen in America; *F*, similar to *E*, but from a preparation made by Zander in Germany. (Original.)



FURTHER STUDIES ON NOSEMA APIS AS REVEALED BY THE MICROSCOPE.

G, *Nosema apis* as seen in a stained smear preparation; *H*, a stained smear preparation showing within the groups how closely the cells are packed with parasites (note the nucleus of an epithelial cell below and to the right of the center); *I*, smear showing young forms (note the paired appearance); *J*, portions of epithelial cells are shed into the lumen of the stomach, carrying with them the contained parasites, accounting for the groups in this photograph; *K*, cross sections of Malpighian tubules highly magnified (the epithelial cells of the one to the left are not infected, some of those of the one above contain parasites, while all of those of the one to the right are heavily infected); *L*, tangential section of stomach wall showing the three muscular layers, the fiber of all of them being branched and striated. The inner and outer layers are made up of longitudinal fibers while the middle one consists of circular ones. (Original.)

growth and multiplication of the parasite. The digestive fluids are believed to assist in removing the spore coat. The liberated young parasite finds its way to the walls of the stomach and invades the epithelial cells. Within this epithelial tissue it grows and multiplies with great rapidity, giving rise finally to numerous spores. The cells of the epithelium at times seem to become virtually filled with the parasites (fig. 3; Pls. II and III). That portion of an epithelial cell that is normally shed into the lumen of the stomach in case of infection bears with it many spores. These are liberated gradually from the fragments, become mixed with the partially digested food of the stomach, and are carried onward first into the small and then into the large intestine and finally pass out of the alimentary tract with the excrement. Other bees ingesting these spores become infected. This in brief is the life cycle [1] through which the parasite passes.

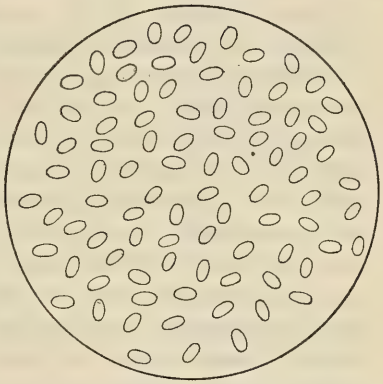


FIG. 4.—Spores of *Nosema apis* as seen in a fresh preparation, indicating their general oval form. (Original.)

Nosema apis reaches the tissues of the bee by way of the alimentary tract. In infecting the stomach the parasite reaches the basement membrane but does not penetrate it (Pls. II and III). The muscular part of the organ is therefore uninvolved (fig. 3). Likewise when the infection is found in the Malpighian tubules the germ does not proceed beyond the basement membrane (Pls. II and III). Furthermore the germ does not infect (fig. 1) the pharynx (*Phy*), the œsophagus (*Œ*), the honey sac (*HS*), the proventriculus (*Pvent*), the small intestine, or the large intestine (*Rect*)—organs which possess a pronounced chitinized intima. Infection with the parasite seems, therefore, to be confined to the epithelium of the stomach and of the Malpighian tubules. So far the writer has not encountered the germ in the blood, musculature, or any of the other tissues of the body.

Nosema apis has not been cultivated in pure cultures by artificial methods. The nature of the organism makes the accomplishment of such a task at the present time especially difficult. Direct proof obtained by the inoculation of bees with cultures of the parasite has not, therefore, been obtained. Fortunately such direct proof is not

[1] Fantham and Porter (1911 and 1912) encountered a parasite in bees taken from colonies affected with Isle of Wight disease which they have identified as *Nosema apis*. Their studies on the morphology of the parasite are interesting.

The morphology of *Nosema apis* and of *Nosema bombycis* are apparently quite similar and studies made by Stempell (1909) on the latter parasite may be referred to with profit in studying *Nosema apis*.

always necessary to establish the causal relationship between the germ and the disease.

Because of the absence of any of the higher animal parasites and of fungi in bees suffering from Nosema-disease these groups of parasites naturally can be eliminated as possible causal factors. Malden (1912, 1913) studied the bacteriology of Nosema-infected bees. He found that the number of bacteria in the diseased bees was much greater than in normal ones, the proportion being as 12 to 1. He found, however, no evidence of a direct etiological relation existing between these bacteria and the disease. Whether they play a secondary rôle is a question which admits of much discussion but one which is somewhat foreign to the present paper.

Some preliminary experiments were made by the writer in regard to the possibility of the presence of a filtrable virus in Nosema-disease. The results obtained indicate that no such virus is present.

By thus eliminating, at least tentatively, the higher animal parasites, the fungi, the bacteria, and the filtrable viruses—groups of parasites which cause diseases in animals—there remains another group, the protozoa. Of this group there is only one species, *Nosema apis*, that is constantly present in Nosema-disease. Other protozoa are occasionally encountered in adult bees, but when found are present usually in small numbers only. The conclusion is naturally reached, therefore, that *Nosema apis* is the cause of Nosema-disease. Such a conclusion is in harmony with views generally accepted at the present time in regard to proof necessary to establish the causal relation of such a germ to the disease.

PREDISPOSING CAUSES.

AGE.

Experimental inoculations have shown that in general adult bees of all ages are susceptible to Nosema infection. In nature it is found that the youngest bees are always free from infection and that the old shiny bees usually are. The absence of *Nosema apis* in the younger ones may be attributed simply to the fact that they have not yet been infected through the taking of food containing the germ. In the case of the shiny bees it seems probable that they have escaped infection, although it is possible that some of them might have been infected at one time and later recovered.

The brood does not seem to be at all susceptible to infection with *Nosema apis*. In heavily infected colonies the larvæ and pupæ apparently remain healthy. In these studies larvæ were inoculated more or less directly by means of a pipette and examinations [1] were made daily following the inoculation. The spores were found mixed with

[1] The examinations were made through fixing and sectioning inoculated larvæ.

the food within the stomach for from 1 to 3 days after the inoculation, but there was no evidence that the parasite had increased in numbers or that it had invaded the tissues.

SEX.

Nosema infection is encountered most frequently in workers, although drones and queens are susceptible. In nature it is not unusual to find from 10 to 20 per cent of the workers of diseased colonies infected. Frequently a much higher percentage is encountered. In no instance has the writer found Nosema infection in drones taken from colonies in which the disease occurred in nature. In a few instances only were the queens that were examined from such colonies found to be infected.

As a result of artificial inoculation practically 100 per cent of the workers of the experimental colony become infected. If drones are present a very large percentage of them also become infected.

Queens in experimental colonies may or may not be found infected. To obtain data relative to queens a number of inoculations were made. Table I summarizes the experiments together with the results obtained.

TABLE I.—*Nosema infection in queens in experimental colonies.*

Date of inoculation.	Period before examination.	Workers infected.	Results of inoculation.
	Days.	*Per cent.*	
Mar. 11, 1913	8	100	Queen not infected.
July 12, 1913	13	100	Do.
Do	16	100	Do.
Mar. 3, 1914	19	100	Do.
Oct. 5, 1914	22	40	Do.
Oct. 19, 1914	23	50	Do.
Oct. 29, 1914	48	100	Do.
Do	53	100	Do.
Feb. 4, 1915	23	.....	Queen Nosema infected.
Sept. 16, 1914	42	100	Do.
Nov. 20, 1912	48	100	Do.
Oct. 29, 1912	53	100	Do.
Aug. 6, 1914	162	100	Do.

It will be seen from the foregoing table that out of the 13 experimental colonies 9 of the queens upon examination were found to be free from infection while the other 5 were infected. Infection in the queen occurs less frequently, apparently, when the inoculations are made in the spring and summer than when made in the autumn or winter. Queens in colonies inoculated and kept at room temperature were found infected in some instances and not in others although practically 100 per cent of the workers in all of them became infected.

RACE.

In experiments recorded in the present paper the bees used have been largely hybrids, being for the most part grade Italians. Two each of tested Carniolans and Caucasians and a few common blacks have been among the colonies used. The bees were found to be susceptible to Nosema infection in all instances. It is not unlikely that future studies will show a difference among the races as to their relative immunity to the disease, but sufficient data are yet wanting to justify a definite statement in regard to the point.

CLIMATE.

Nosema infection has been reported from Australia (Price and Beuhne, 1910), Brazil (Zander, 1911), Canada (White, 1914), England (Fantham and Porter, 1911), Germany (Zander, 1909), and Switzerland (Nussbaumer, 1912). Studies have not yet been made in Denmark on the disease (Bahr, 1916). The writer (1914) has found it in samples of bees received from 27 different States of the United States. Out of 120 samples examined 40 contained the parasite. Samples showing infection were received from the coast plains and mountains of the East, from the plains of the Mississippi Valley, from the plateaus and plains of the West, and from the South and the North.

The infection was found in bees received from Florida and southern California, but in 15 samples received from Texas it was not found. The data thus far obtained indicate that less infection occurs in the southern portion of the United States than farther north. Whether it is found in the Tropics or in the coldest climate in which bees are kept is not yet known.

Laidlow (1911) reports that heavier infection was encountered in some parts of Australia than in others. Nussbaumer (1912) reported the infection from 14 of the cantons of Switzerland.

The practical import of these observations in connection with the climate, to the beekeepers of the United States at least, is that the presence of the disease in a region can not be attributed entirely to the climatic conditions present. It is possible, however, that the climate of a particular region may affect somewhat the occurrence and the course of the disease in that locality.

SEASON.

Infection in apiaries has been found to occur at all seasons of the year, but is greatest during the spring. In the studies reported in the present paper (p. 20) infection was greatest in April and May, being greater in these months than in March. Very little of a definite character is known of the infection as it occurs in nature during the winter. Experimentally it has been found that bees are susceptible to infection with *Nosema apis* at all seasons of the year.

FOOD.

As is pointed out under the heading "Climate," Nosema-disease occurs in a wide range of localities. The food and water obtained in these localities naturally differ as to quality and quantity. Infection is found in colonies having an abundance of stores and in others having a scarcity. The disease is produced readily by experimental inoculations in colonies with much and in colonies with little stores. From these observations the conclusion seems to be justified that the rôle played by food in the causation of Nosema-disease is slight, if indeed it contributes at all appreciably to it.

A THREE-YEAR STUDY OF NOSEMA INFECTION IN AN APIARY.

The presence of Nosema infection among bees in the apiary of the Bureau of Entomology was discovered in May, 1910 (White, 1914) In April, 1912, a more or less systematic study was begun on the prevalence and persistence of the infection in the apiary and was continued until June, 1915, As the apiary was being used for other purposes than these studies, it was not possible to follow all of the colonies throughout this entire period. In Table II are summarized observations made during the first year of the study.

TABLE II.—*Results obtained from April, 1912, to March, 1913, inclusive, in a study of Nosema infection in an apiary.*

Colony No.	1912																												1913		
	April.		May.				June.		July.			August.		September.			Per cent.	Experiment No. 1.	October.								December.		March.		
	12	20	2	10	23	28	2	28	2	24	30	2	14	9	13	18			5	8	11	16	18	21	28	30	17	17	12	25	
1	0e		2e	2p		2e		1p		3p				0p			14					0p			0e					0e	
2																1p				0p					2e	0e				0e	
4																0p									0e						
5	3e		1e	3p				2p		2p							22		0p			0p			0e					0e	
6	9e		D														90														
6a															1p			1	6p		5p		S		8e		3f	M	D		
7	3e		3e		3p			1p		3p							26		0p					1p	3e					0e	
8																				0p		6p			0e					0e	
10																						0p			0e						
11	0e		1e		4p			1p		R																					
12	0e		0e		2p			0p		2p				1e			8	2	7p		4p		S		9e		7f	M	4f	8f	D
14	10e		10e		D												100														
18																								7p		0e					
19																			0p						1e					0e	
21	0e		2e		1e			1p									10														
23	1e		0e		5p			4p						1p			22					3p		0e					0e		
25															2p			3		10p	5p	10p	W		10e		10f	W	D		
26																						9p		1e						0e	
28	8e		D														80														
29																						7p		0e							
30																								7p		0e					
31																					4p					0e	0f				
35														0p	1p			4	9p		4p	10p	S		9e	1e	10f		6e		
36		1e	1e		3e			6p			2p						26					7p				1e				1e	
38		3e			1p				0p		1e						12				8p				2e						
40																								7p		1e					
41														1p				5		6p	6p		W		10e	10e	5f	W	D		
42		0e	1e		5p				1p		1p						16														
44		3e	2e		3p												27						8p								
49																							6p			0e				1e	
50		0e	0e		1p				2p								7						8p			2e				0e	
51		10e	10p		1f	D																									
52																															
53												1p	3p										9p			0e					
54																									6p	1e					
55														0p	2p			6			5p		M		1e	2p					
56																									3e		3f	W	0e		
																									5e	6p					

57		5^{e}	D														50														
59		1^{e}	1^{e}			2^{p}	0^{p}										10														
60																								9^{p}	1^{e}	1^{e}					
63		2^{e}				3^{e}			0^{e}				1^{p}				15					1^{p}									
65		0^{e}	0^{e}			1^{p}	1^{e}						1^{e}		0^{p}		5	7			10^{p}		M	8^{p}			4^{f}	M	2^{e}		
66														1^{p}				8	7^{p}		7^{p}	8^{p}	W		8^{e}		5^{f}	D			
67														1^{p}				9				8^{p}	M		9^{e}		0^{f}	W	0^{e}		
68		3^{e}	3^{e}			2^{p}	1^{e}										25								5^{p}	3^{e}			0^{e}		
69													3^{p}												2^{e}	6^{p}			0^{e}		
70														0^{p}	2^{p}			10	5^{p}				S		4^{e}		2^{f}	M	0^{e}	2^{e}	
72																									5^{p}	1^{e}				0^{e}	
73		6^{e}	0^{e}	5^{h}	5^{p}				0^{e}		4^{p}						33								5^{p}	1^{e}				0^{e}	
75																									0^{e}	5^{p}				0^{e}	
77		2^{e}	2^{e}			0^{p}	1^{e}						5^{p}				20														
79		2^{e}	3^{e}			0^{e}	0^{e}										12								1^{e}					1^{e}	

Explanation for Table II.—The number of Nosema-infected bees found in each sample of 10 bees examined is recorded. The colony from which the sample was taken is shown by its number in the first column. The results are given in columns headed by the approximate date on which the examinations were made. Approximate dates are used to abbreviate the table. As a rule they are within two days of the exact dates. The letter accompanying a number indicates the source from which a sample was taken; the letter "e" showing that the sample was taken from among the bees about the entrance of the hive; "p," that the bees examined were carrying pollen primarily when taken; "h," that they were carrying honey or water; and "f," that they were taken from the brood frames. The letter "D" shows that the colony was dead; "R," that it was removed. "S" indicates that the colony was relatively strong; "M," that it was medium in strength; and "W," that it was relatively weak.

From Table II it will be noted that in April there were 24 colonies in the apiary. Out of 240 bees examined from them during the month, 72 (30 per cent) were Nosema infected. The number of bees out of each sample of 10 was found to vary from 0 to 10.

During May, out of 410 bees examined 96 (23 per cent) were found to be Nosema infected.[1]

During June, out of 130 bees taken from 13 colonies 19 (15 per cent) were found to be Nosema infected.

During July, out of 130 bees examined 21 (16 per cent) were found infected.

During September, out of 170 bees examined 14 (8 per cent) proved to be Nosema infected.

Out of a total of 1,140 bees examined in 1912, from April to September, inclusive, 236 (20 per cent) Nosema infected bees were found. The number of infected bees found in the different colonies varied from 5 to 100 per cent.[2]

Five of the 24 colonies died. These were dead by the end of May. It was found that the number of infected bees present in them varied from 50 to 100 per cent. The number of infected bees in the colonies that lived varied from 5 to 33 per cent.

All of the colonies that died were weak when first examined in the spring and dwindled until they disappeared. The colonies that lived gained in strength and behaved as healthy ones.

The colonies that died had sufficient stores. The queen in each of them was apparently in good condition and brood was being reared. At times, indeed, the brood was in excess of the amount that could properly be cared for by the diminishing number of bees present. These and other facts which have been observed justify the belief that the immediate cause of death in each of the five colonies that died was the Nosema infection that was present. These colonies, therefore, may be said to have died of Nosema-disease.

The number of colonies in the spring was increased during the bee season through swarming and by division.

In September an experiment was begun in the apiary in which 10 colonies were inoculated with *Nosema apis*. The results of these inoculations will be referred to later under experiment No. 1 (p. 23).

Examinations were made in 1913 for the prevalence and persistence of Nosema infection in the apiary studied in 1912. Naturally the colonies present were not altogether the same as those of the previous year. Some of them had been lost and some represented the increase. The results obtained are summarized in Table III.

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[1] Fractions are omitted in this paper, as a rule.

[2] As the younger bees and the older ones were avoided in selecting samples for examination, the results recorded in this paper show a higher percentage of Nosema-infected bees in the colonies than actually existed.

TABLE III.—*Results obtained in 1913 from a study of Nosema infection in an apiary.*[1]

Colony No.	Experiment No. 1.	March.		May.	June.		July.				Experiment No. 2.	August.		September.	October.			Per cent.
		12.	25.	29.	3.	18.	14.	16.	19.	22.		9.	25.	23.	13.	18.	28.	
1			0^e															
2			0^e			1^e		0^p				0^e						2
5			0^e			1^p			0^p					1^p				5
7			0^e			1^p								2^p				10
8			0^e			0^e			1^e									3
12	2	4^f	8^f	D														60
26			0^e			0^e						0^e	2^e					5
30			1^e	R														
31			1^e	R														
35	4	6^e		0^p	3^h		1^e			1^e		0^e	0^e					16
36			1^e			0^p	3^e				A			6^p			0^e	20
48			1^e			0^p		0^e				1^e		1^p				6
49			1^e			0^e			0^e			1^e		2^p				8
50			0^e			0^e		1^e			B	0^e		2^p		1^e		7
55	6	0^e		3^f														
61											C	0^e		9^p			0^e	30
65	7	2^e		0^e	0^p	0^p	1^e					1^e	0^e					6
66						1^p		1^e			D	2^e		2^p			0^e	12
67	8	0^e		0^e	0^e		0^e			2^h		1^e	0^e					4
68			0^e			0^p	3^e				E	0^e		3^p	0^e			10
69			0^e				0^p	1^e						1^p				5
70	10	0^e	2^e	4^e		0^p	0^e			1^e		1^e						11
72			0^e			1^e	0^e			5^h		0^e	0^e					10
73			0^e			0^e	0^e							0^p				0
75			0^e			0^e	0^e											0
79			1^e			0^e		1^e				1^e		0^e				6
81			0^e															
82											F	0^e		1^p			0^e	3
a						0^p		0^e				1^e	0^e	2^p				6
b						0^p			0^e					3^p				10
c													0^e					
d													0^e	4^e				20
e							1^e							4^p				25

[1] Where the number of bees examined is small, the rate indicating the percentage frequently is not given.

Explanation for Table III.—The method of recording results is the same as in Table II. Colonies examined in 1913 that were examined in 1912 bear the same numbers in Table III as in Table II. Colonies representing the increase in the spring are designated by the letters "a" to "e," inclusive. Colonies in experiment No. 1 are indicated by numbers; colonies in experiment No. 2, by capital letters.

From Table III it will be observed that in March, 1913, out of 270 bees examined from the 25 colonies then in the apiary 28 (10 per cent) were found to be Nosema infected.

During June bees were examined from 21 colonies, and out of 220 bees 8 (4 per cent) were found to be infected.

During July 21 colonies were examined and out of 260 bees 23 (9 per cent) were found to be infected.

During August bees from 18 colonies were examined and out of 240 bees 11 (5 per cent) were found to be infected.

During September, out of 170 bees from 17 colonies 43 (25 per cent) were found to be infected.

During October bees were examined from 6 colonies only, and out of 60 bees 1 (2 per cent) was found to be infected.

Out of a total of 1,270 bees examined during the year 1913, 121 (10 per cent) were infected, being less than the percentage found in 1912, which was 20 per cent. The spring infection was very much less in 1913 than in 1912.

The percentage of infected bees found during the spring and summer remained quite constant, increasing unexpectedly in September. The reason for the increase can not be assigned at present.

Out of the 25 colonies in the apiary in March, 1913, 1 (No. 12) died. As this colony contained a high percentage of Nosema-infected bees, and as it dwindled until it disappeared, it may be assumed that Nosema-disease was the immediate cause of its death. As in the preceding year all of the colonies that lived behaved much as do uninfected ones.

In this year another experiment was begun in the apiary. This one is described as experiment No. 2 (p. 25).

Studies similar to these made in 1912 and 1913 were continued throughout 1914 and until June, 1915. While in the main the colonies of the apiary were those of the previous years, naturally there had been some changes. The results obtained are summarized in Table IV.

TABLE IV.—*Results obtained from May, 1914, to June, 1915, from a study of Nosema infection in an apiary.*

Colony No.	1914												1915					
	May.					June.			July.	September.		November.		March.		April.		May.
	2	8	12	15	27	5	8	18	15	10	23	5		2		8	25	7	26
1	0e	1p	....	0p	1p	0p	5p	0p	0p	0p	0p	0e	....	0e		0e	0p	0p	0h
2	2e	2p	....	1p	1h	0p	....	0p	0p	0p	0e	0e	....	....		....	....	....	....
3	1e	1e	....	3p	2h	1p	....	1p	0p	0p	0e	....	....	....		....	....	....	....
4	1e	1p	....	1p	2h	0p	....	0p	....	0p	0e	0e	....	....		....	....	....	....
5	0e	1p	....	1p	2h	0h	....	1p	0p	0p	0e	0e	....	0e		0e	0p	1p	0h
6	0e	0p	....	1p	2h	0p	....	0p	0p	0p	....	....	....	....		....	....	....	....
7	1e	2p	....	0p	2h	1h	....	1p	0p	0p	0e	0e	....	....		....	....	....	....
8	0e	0p	2p	....	1h	0e	....	0p	0p	0p	0e	0e	....	5e		0e	D	....	....
9	1	0p	....	0p	4h	0h	1p	1p	0p	0p	....	....	....	....		....	....	....	....
10	0p	2e	....	2e	1h	0p	2p	0p	0p	0p	....	....	....	....		....	....	....	....
11	1e	1p	....	0p	1h	0h	....	0p	0p	0p	....	....	....	....		....	....	....	....
14	2e	2e	....	2e	0e	1e	....	0p	0p	0p	....	....	....	....		....	....	....	....
15	1e	1p	....	2p	2h	2h	....	0p	0p	....	....	....	....	....		....	....	....	....
16	2e	2p	....	2p	1h	0h	1p	0p	1p	....	....	....	....	....		0e	....	....	....
17	2e	4p	....	1p	4h	0h	1p	0p	1p	0p	....	....	....	1e		0e	....	1p	0h
18	0e	1p	....	1p	3h	1h	3p	1p	0p	....	....	....	....	0e		5e	D	....	....
19	0e	0p	....	1p	2h	2h	2p	0p	0p	....	....	....	....	....		0e	0p	0h	0h
20	1e	1p	....	2p	1h	1h	3p	0p	0p	....	....	....	....	....		0e	0p	0p	0h
21	1e	3p	....	0p	2h	1h	1h	0p	....	....	....	....	....	....		0e	1p	0p	0h
22	0e	2p	....	2p	3h	2h	2p	1p	....	....	....	....	....	....		....	....	....	....
"7"	0e	2p	....	2p	1h	0p	1p	1p	0p	....	0e	....	s	....		0e	0e	....	....
"36"	3e	....	....	2p	3h	0h	3p	1p	0p	....	....	....	t	....		0e	0p	....	....
"50"	4e	4p	....	3p	2h	1p	3p	0p	0p	0p	....	....	u	....		6e	2e	1p	0e
"66"	2e	2p	....	0p	....	....	2h	1p	....	....	....	....	v	....		0e	0e	0e	0e
"68"	0e	2p	....	0p	3h	0p	0p	0p	0p	....	....	....	w	....		0e	....	....	....
"73"	7e	5e	....	4p	6h	1p	1p	3p	0p	....	....	....	x	....		0e	....	....	....
"82"	1e	3p	....	1p	....	0h	2p	1p	0p	....	....	....	y	....		0e	9e	9p	1e
													z	....		0e	1e	3p	0e

Explanation of Table IV.—The colonies reported in Table IV for 1914 do not bear the same numbers that were assigned to them for 1913 in Table III except those designated by numbers in quotation marks. The first 9 colonies reported in the table for 1915 bear the same numbers they did in 1914. The identity of colonies numbered by letters "s" to "z," inclusive, had been lost through changes made in the apiary.

Table IV shows that out of 1,050 bees examined during May, 1914, 166 (16 per cent) were Nosema infected.

In June, out of 700 bees examined 60 (9 per cent) were found infected.

In July, out of 240 bees examined 2 (1 per cent) were infected.

In September, 220 bees were examined and no Nosema-infected one was found.

In November, 60 bees were examined and none was found infected.

Out of 2,270 bees examined during the summer of 1914, 218 (10 per cent) were found infected.

It will be noted that during the early months of the active bee season of 1914 there was a higher percentage of Nosema-infected bees in the apiary than during a similar period of 1913.

Two colonies were so weak in May that they were disposed of. In one of these at least (No. 13) the weakness was most probably due to Nosema infection.

During the first week in July the apiary was moved to a new location. It is interesting to note that the amount of Nosema infection after removal was reduced to practically nothing. This is not definitely accounted for by the results obtained by these investigations.[1]

Examinations were made of a portion of the apiary in 1915. In March, out of 50 bees taken from 5 colonies, 6 (12 per cent) were found to be Nosema infected.

In April, out of 280 bees taken from 17 colonies 24 (9 per cent) were found infected.

In May, out of 200 bees taken from 10 colonies 16 (8 per cent) were infected.

Out of 530 bees examined from the apiary during the spring of 1915, 46 (9 per cent) infected ones were found.

Among the colonies that were examined during the spring of 1915 two (Nos. 8 and 18) died by the end of April. Both of these contained a rather high percentage of Nosema-infected bees. Two others containing an equal or greater number of infected bees lived throughout May and had recovered apparently by June. In case of these 4 colonies it can properly be said that the two colonies that died died of Nosema disease, whereas the two that lived recovered from it.

In Table V is given a summary of the results obtained in the study of the apiary from April, 1912, to June, 1915.

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[1] That the immediate environment of the apiary determines, to some extent, the presence or absence of Nosema-disease and its transmission seems quite likely. In searching for the cause for such a difference the water supply of the bees, if near by, must not be overlooked (p. 46). In this connection, it may be pointed out that in the experimental apiary (Pl. IV) Nosema infection at no time exceeded 1 per cent, excepting naturally in inoculated colonies, although the source from which these colonies were obtained had been largely the apiary which, it will be seen from Tables II and III, showed Nosema infection in from 10 to 20 per cent of the bees. Here there was no slowly moving body of water used by the bees as the source of their water supply.

TABLE V.—*Summary of results from a study of Nosema infection in an apiary.*

Year.	March.			April.			May.			June.			July.		
	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.
1912	.....	.....	.....	240	72	30	410	96	23	130	19	15	130	21	16
1913	270	28	10	.....	.....	.....	50	7	.....	220	8	4	260	23	9
1914	.....	.....	.....	.....	.....	.....	1,050	166	16	700	60	9	240	2	1
1915	50	6	12	280	24	9	200	16	8	.....	.....	.....	.....	.....	.....
Total	320	34	11	520	96	18	1,910	285	17	1,050	87	8	630	46	7

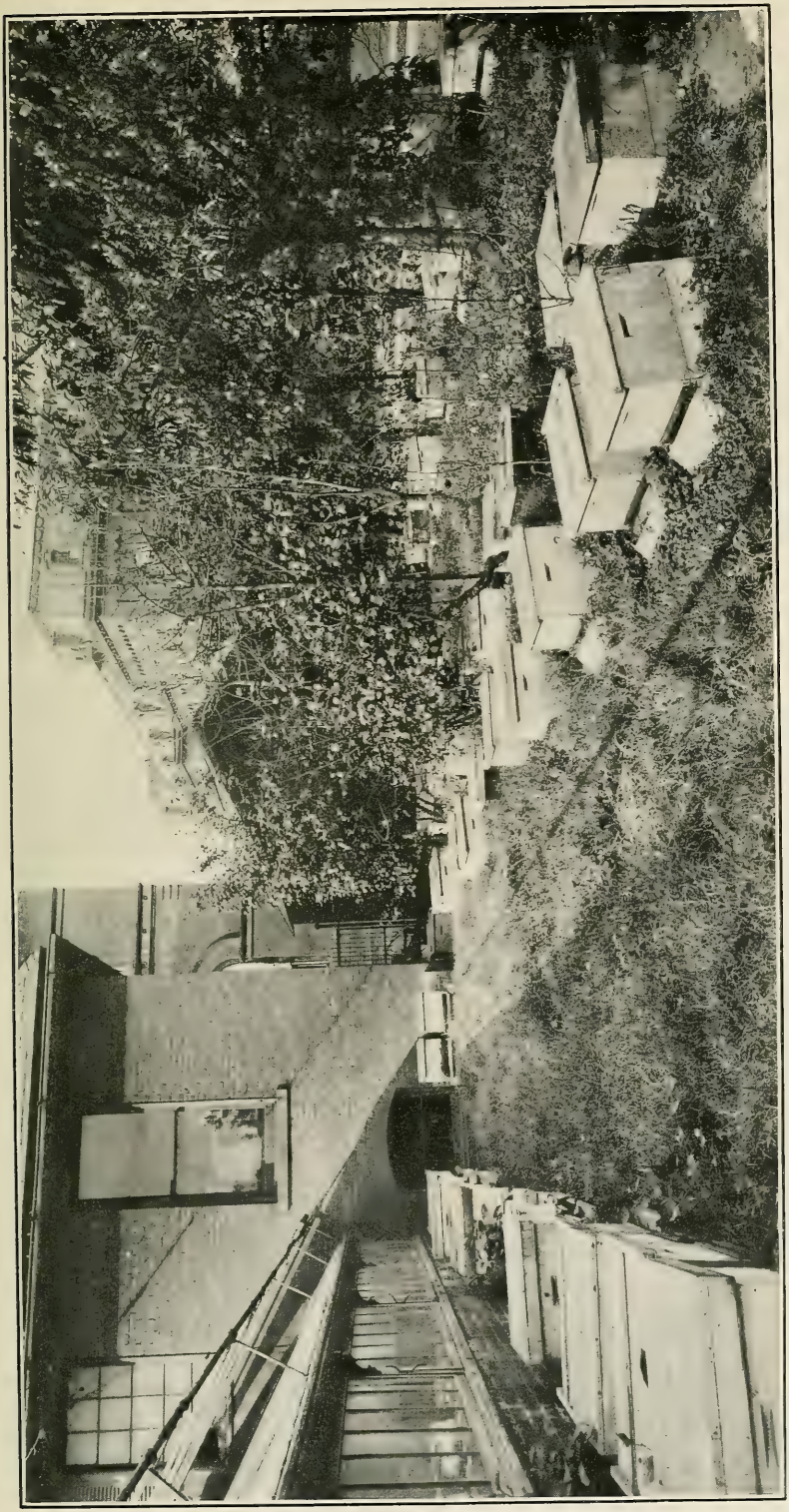
Year.	August.			September.			October.			Total bees examined.	Total Nosema infected.	Per cent.
	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.	Bees examined.	Nosema infected.	Per cent.			
1912	60	14	.....	170	14	8	.....	.....	.....	1,140	236	20
1913	240	11	5	170	43	25	60	1	.....	1,270	228	10
1914	.....	.....	.....	220	.....	.....	.....	.....	.....	2,210	121	10
1915	.....	.....	.....	.....	.....	.....	.....	.....	.....	530	46	9
Total	300	25	8	560	57	10	60	1	.....	5,150	631	12

From Table V it will be observed that the number of infected bees found at different periods of the year varied considerably. April and May furnished the highest percentage, being 18 and 17 per cent respectively. In March, June, July, August, and September the number of Nosema-infected bees among those examined was 11, 8, 7, 5, and 10 per cent respectively. Out of 5,150 bees taken from the apiary from April, 1912, to June, 1915, and examined, 631 (12 per cent) were Nosema infected.[1]

Laidlow (1911) reports that out of somewhat more than 1,500 bees received from various parts of Australia, 17 per cent were found to be Nosema infected.

From an examination of the foregoing tables it is seen that Nosema infection was found to be present in practically every colony of the apiary. Had further examinations been made of the few colonies in which *Nosema apis* was not found, one could well expect, from what is known of the disease, that these, too, would have revealed the presence of the infection. It is seen also that the infection persisted throughout all seasons of the year, and that it was heaviest

[1] While this three-year study was being made the apiary served for other work. It is likely that the attending manipulations were accompanied from time to time by a certain amount of robbing. From the nature of the disease, however, it is not believed that this fact affected materially the results obtained.



EXPERIMENTAL APIARY IN WHICH THE NOSEMA-DISEASE EXPERIMENTS MADE DURING THE SUMMER OF 1915 WERE CONDUCTED. (AUTHOR'S ILLUSTRATION.)

in the spring. Some colonies died as a result of the disease, while a greater number recovered from the infection, increased in strength, and behaved in all respects as healthy colonies.

The total of all the spring counts, during the period from 1912 to 1915, inclusive, of the apiary under study, was 94 colonies. Out of this number at least 12 (13 per cent) died more or less directly as the result of Nosema disease. An equal or greater loss to the apiary than this colony loss probably is the aggregate loss in strength sustained by colonies weakened by the infection but which recover from the disease.

Naturally it is particularly unfortunate from an economic point of view that the highest percentage of infected bees, and consequently the heaviest loss in strength sustained by colonies from Nosema infection, occurs in the spring.

Beuhne (1916) has reported investigations made on colonies from his own apiary which are similar in nature to the foregoing studies. The results he obtained indicate that Nosema infection in Australia is similar to the infection as it occurs in America.

SYMPTOMS OF NOSEMA-DISEASE.

Nosema-disease presents only a few symptoms. In describing them the colony rather than individual bees should be considered as the unit, since it is the colony as a whole that is of primary interest to beekeepers.

Weakness is a colony symptom which invariably will be manifest if a sufficiently large percentage of the bees of the colony are Nosema infected and if the infection persists for a sufficient period. When only a small percentage of the bees are infected the weakness resulting may never be apparent. The loss in strength may be gradual or sudden.

The behavior of a Nosema-infected colony is similar to that of a healthy one. The stores are sufficient. The queen does her work well. As the colony dwindles the queen usually is among the last handful of bees. The brood in general is normal in appearance, but in colonies weakened by the disease not infrequently it is seemingly in excess of the amount that can be properly cared for by the adult bees present.

In Nosema-disease the workers especially suffer from the infection. An infected bee manifests no outward symptoms of the disease when seen among the other bees of the colony and it performs functions similar to those performed by healthy ones.

When the stomach of an infected bee is removed it may show marked changes which are characteristic of Nosema-disease. The organ pales as a result of infection. The brownish yellow or dark reddish hue of the normal stomach is gradually lost as the disease advances. The organ (Pl. I) is often increased in size, the circular

constrictions are less marked, and the transparency is diminished. In late stages of the disease, however, the stomach approaches the normal in size and the constrictions are again well marked. The organ is then white and opaque and the tissues are friable and easily crushed. When crushed the mass presents a milky appearance.

Upon microscopic examination *Nosema apis* is found in very large numbers in the crushed tissues. The presence of the parasite is almost invariably recognized by its spore form. The presence of Nosema-infected bees in a colony is the one constant colony symptom of the disease.

METHODS EMPLOYED IN EXPERIMENTAL STUDIES.

As *Nosema apis* has not been grown in the laboratory by artificial methods, in carrying out these investigations it has been necessary to inoculate a large number of colonies of bees. The use of a few bees in cages was found to be inadequate for experimental purposes. A 4 to 6 frame nucleus in a 10-frame hive body (fig. 5) serves well the purposes of an experimental colony. The experimental apiary (Pl. IV), consisting usually of about 50 colonies, was the same one that was used in the sacbrood studies. During the bee season the colonies were inoculated and kept in the apiary in the open under conditions similar to those occurring in nature. Precautions similar to those observed in the sacbrood studies were followed in the present studies. During the winter colonies to be inoculated were removed to and kept in the laboratory. The top of the hive body was screened and the bees given free opportunity for flight through a hole in the window.

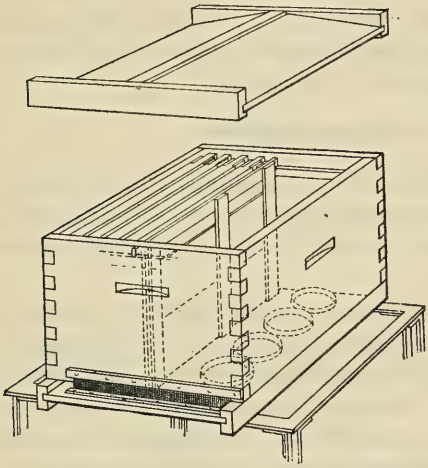


FIG. 5.—Experimental hive, having four Hoffman frames, a division board, Petri dishes as feeders, the entrance nearly closed with wire cloth, and the opening on the side of the hive body occupied by the frames. (Original.)

The manner of obtaining the parasite *Nosema apis* from diseased bees for use in the inoculations is described under "Diagnosis" (p. 48). The stomachs of from 5 to 10 infected bees are amply sufficient for each inoculation. After their removal from the bees they are crushed, suspended in sirup, and fed to a colony free or practically free from Nosema infection. The methods throughout are similar

in general to those employed and described in the sacbrood studies. It should be stated in addition that no watering place for the bees was provided at the time of these experiments and none with sluggish water was near by.

The results of an experiment usually can be determined during the second week following the inoculation. The diagnosis is made as described later in the present paper (p. 48). Usually one examination of 10 bees is sufficient for the determination of results. It is advisable sometimes, however, to make others.

As a rule experimental colonies inoculated during the summer recover from the infection and can be used again. The period which must elapse, however, before they can be used for a second experiment varies. An examination of the field bees should show no infection among them or only an occasional infected bee before another inoculation is made. A colony used in the laboratory is good for one inoculation only if by it Nosema-disease is produced. Should the results be negative following an inoculation, however, the colony may be used in a subsequent experiment.

It is not necessary to disinfect a hive which has housed a Nosema-infected colony. The experimental colony may or may not have a queen. If one is present no concern need be felt in regard to whether or not she is infected. No fear need be entertained that drones from infected colonies in the apiary will transmit the infection to the experimental colony.

EFFECT OF NOSEMA INFECTION ON THE COLONY AND ON THE APIARY.

To determine the effect which Nosema infection in a colony produces on the colony, and on the apiary of which the colony is a part, is a problem in the study of Nosema disease which is of vital interest to the beekeeper. Some observations have been made bearing directly upon this point.

EXPERIMENT NO. 1.

On September 13, 14, 15, and 18 ten colonies were fed a sirup suspension of the crushed intestines of Nosema-infected bees. These colonies (Table II, Nos. 6*a*, 12, 25, 35, 41, 55, 65, 66, 67, and 70) were in the apiary mentioned on page 13. Those selected for inoculation were not especially strong, the bees being easily accommodated on six or seven brood frames and being about an average for the apiary. Examinations show that about 10 per cent of the pollen-carrying bees of these colonies were Nosema infected at the time of the inoculation. The 32 uninoculated colonies in the apiary served as checks.

It will be seen from Table II that after inoculation 50 to 100 per cent of the pollen-carrying bees in the inoculated colonies were Nosema infected. Out of the 100 bees examined from these colonies

during the period from October 5 to October 16, inclusive, 132 (70 per cent) were found infected. These colonies when examined on October 28 showed that, out of 100 bees examined, 78 (78 per cent) were infected. It will be noted, therefore, that following the feeding inoculations there was a marked increase in the percentage of Nosema-infected bees in each of the 10 colonies inoculated.

In the experiment sufficient precautions were not taken to prevent robbing at the time the inoculations were made. This resulted in an increase also of Nosema-infected bees in some of the uninoculated colonies (Table II) of the apiary—the checks. The increase in the number of infected bees disappeared more readily from the check colonies, however, than from the inoculated ones, suggesting that probably a comparatively small amount of the contaminated sirup was obtained by the robbing bees.

On December 17, out of 100 bees taken from the 10 inoculated colonies 49 (49 per cent) were found to be Nosema infected, showing that the percentage of infected bees had decreased.

From comparison of the inoculated colonies in October and in December, it was observed that their strength had decreased and that they were relatively weaker than the checks. Toward the last of December one of the 10 inoculated colonies died. During the last week of the year the remaining 9 were packed for the winter as were also the check colonies. Some of the weaker check colonies were united, giving them a slight advantage in strength over the inoculated ones.

The winter 1912–13 being a favorable one for bees, the winter losses were low. In March, 1913, when the first examination of the apiary was made, 4 of the 10 colonies that had been inoculated had died out. Four of the six inoculated colonies that were still alive showed 4, 6, 2, and 2 Nosema-infected bees respectively in samples of 10 bees examined. Neither of the other two inoculated ones showed at the time the presence of Nosema infection. All of the 19 uninoculated colonies packed in December were alive in March, 1913. Out of 190 bees caught from the entrance of these check colonies during March only 6 (3 per cent) were Nosema infected.

By the middle of May another of the inoculated colonies (No. 12) had died, making 5 in all. Of the 10 colonies that had been inoculated in September, 1912, the 5 that lived through the winter and the following spring continued to gain in strength during the summer of 1913 and by autumn were apparently as strong and healthy as any in the apiary.

By experiment No. 1 it is shown that when colonies are inoculated with *Nosema apis* a high percentage of adult bees of each colony becomes Nosema infected—results which confirm similar ones previously obtained by Dönhoff (1857), Zander (1909), and others.

Such results, together with facts which are recorded on the foregoing pages, are sufficient to demonstrate that Nosema-disease is an infectious disease of adult bees.

It is shown also by the results of this experiment that there is a tendency for the infected colonies to become weakened. It is further shown that when inoculated in September colonies do not die out readily as a result of the inoculation. Furthermore the results indicate that the infection is not readily transmitted from the infected to the healthy colonies of the apiary. It is further shown that colonies inoculated in September may die as a result of the infection during the winter that follows, or they may survive the winter, gain in strength during the brood-rearing season, and by the following autumn present the appearance of healthy colonies.

EXPERIMENT NO. 2.

Beekeepers are always desirous of knowing whether combs from diseased colonies can be used in healthy ones without causing a spread of the infection. To obtain data relative to this point experiment No. 2 was begun in July, 1913 (Table III). In the experiment, brood combs from diseased colonies were inserted into colonies comparatively free from Nosema infection and kept under observation for more than a year afterwards.

Combs from the 5 colonies of experiment No. 2, which died during the winter and spring following their inoculation with *Nosema apis* in September, 1912, were inserted into the 6 colonies (Nos. 36, 50, 61, 66, 68, and 82, numbered by capital letters "A" to "F," respectively) used in the present experiment, each colony receiving from two to four combs. The colonies from which the inserted frames were obtained had been dead for from seven weeks to five months before they were given to the colonies. None of the 6 colonies were strong, the bees being easily accommodated on from four to six brood frames, a strength representing about an average for the apiary.

Out of 110 bees examined from the 6 colonies of the experiment prior to the insertion of the combs 10 (9 per cent) were found to be infected; and out of 170 bees examined after they were inserted 26 (15 per cent) were found to be infected. This increase in Nosema-infected bees can not be attributed to the introduction of the combs, since a similar increase is noted in the other colonies of the apiary serving as checks.

All of the colonies of the experiment lived through the winter and spring except one (No. 61). This colony was dead when examined in May, 1914. Dead bees taken from the bottom board of the hive showed a high percentage of Nosema-infected bees. The 5 colonies that survived gained in strength, behaved as healthy colonies, and contained a percentage of Nosema-infected bees approximating that

of the other colonies of the apiary (Table IV, colonies numbered 36, 50, 66, 68, and 82).

The results obtained indicate, therefore, that by inserting combs from Nosema-infected colonies, as was done in experiment No. 2, the infection is not transmitted appreciably. An explanation for this is easily seen from results recorded throughout the present paper. Further experiments on the point are summarized in Table XXVI.

EXPERIMENT NO. 3.

In this experiment 7 colonies free from Nosema infection were inoculated by feeding them sirup to which *Nosema apis* had been added. The bees from which the parasites were obtained for this experiment were from various sources (p. 12). They had been dead and drying in the laboratory at room temperature for at least three months. All of the 7 colonies received the first inoculation feeding on October 8. On each succeeding day for four days the feeding was repeated. Each of the inoculated colonies of the experiment was examined from time to time, but no Nosema-infected bees were found. The final examination in connection with this experiment was made on October 28. Out of 70 bees examined from the 7 colonies only one Nosema-infected bee was found. The infection in this instance probably did not result from the inoculations.

In this experiment it is shown that *Nosema apis* drying in the abdomen of bees at room temperature for three months does not produce infection when fed to healthy bees. This result suggested the interesting fact that the parasite of the bee resisted drying for a comparatively short time only (see other experiments, p. 40).

EXPERIMENT NO. 4.

In experiment No. 4, four of the colonies used in experiment No. 3 were inoculated on October 29, 1912, with *Nosema apis* taken from infected bees recently killed. Nine days after the inoculation samples of bees were examined from each of the four colonies inoculated. Nosema infection was found in nearly all of the bees examined. Two weeks after inoculation 50 bees were examined from each of the 4 colonies. All of the 200 bees were found to be infected. At the end of three weeks a similar condition prevailed. On December 16, 48 days after inoculation, all of the 4 inoculated colonies were alive. A large number of bees were now found on the bottom board of the hive. By this time the colonies had become very much weakened. The bees were uneasy, the cluster being easily disturbed. During the following week 1 of the colonies died out completely. The remaining 3 were chloroformed. Another colony inoculated in November gave like results, and died in January, 1913.

Each of the 5 colonies of the experiment were four-framed nuclei. As the inoculations were made late in the autumn there were no

young bees emerging. All of the bees of the colonies were exposed, therefore, to infection by the inoculation.

It is seen from this experiment that during the autumn workers infected with *Nosema apis* live, as a rule, for more than one month, but that most of them die during the second month after infection. These results led to the conclusion that heavy infection in a colony when no brood is being reared will destroy the colony, but that it may live for two or three months following the infection.

Although 100 per cent of the workers in each of the 5 colonies were infected, the queens from 3 of them were free from infection at the death of their respective colonies. The other 2 were found to be infected.

NOSEMA INFECTION WEAKENS THE COLONY.

There is good evidence at hand indicating that Nosema infection weakens the colony. The fact that the epithelial layer of the stomach is filled with parasites (fig. 3; Pls. I and II) at once suggests that the functions of the organ, digestion and absorption at least, would be decidedly impaired thereby. Likewise, when the Malpighian tubules are invaded (Pls. II and III), it is to be expected that the bee suffers impaired functions. The abnormal condition argues strongly that such a bee is less efficient as a member of a colony than an uninfected one. Further evidence that infection weakens a colony is seen in the fact that in nature the heaviest infection is encountered in the weaker colonies. Still further evidence is seen in the results obtained in experiments Nos. 1, 3, and 4, just recited, and from inoculations made in 1913, 1914, 1915, and 1916, now to be referred to.

On June 4, 1913, a colony was inoculated by feeding it *Nosema apis* in a sirup suspension. On the 13th it was found to be heavily infected. At this time the inoculation was repeated. When examined on July 12 the colony had not increased in strength as the uninoculated ones had done. On this date it was reinoculated. By the middle of August it had not gained in strength. No reason could be assigned for the failure of the colony to become strong other than the presence in it of Nosema infection resulting from the inoculation.

On June 9, 1914, a colony was inoculated with *Nosema apis*. On the 22d it was found to be heavily infected. On July 8 it was reinoculated, at which time it was weaker than the check colonies. On August 6 the colony was still relatively weak and was reinoculated. On the 17th it was still weak. The failure on the part of the colony to become stronger is attributed to the Nosema infection.

On August 6, 1914, a colony was inoculated with *Nosema apis*. It became heavily infected and on September 9 it seemed to be weakened as a result of the infection. It was reinoculated on this date. On December 1 it was found to be heavily infected and on January 15, 1915, it was dead.

On March 30, 1915, a colony was inoculated, resulting in heavy infection with *Nosema apis*. On June 17 the inoculation was repeated. Later a swarm was cast. Inoculations were repeated on July 3, 9, 17, 24, 31, and August 13. The colony became much weakened and later in the autumn died.

Beginning on March 22, 1916, a colony was inoculated at irregular intervals thereafter until September. Much brood was being reared in it throughout the season, but its strength in September was about equal to its strength in March.

The evidence obtained, it will be observed, is sufficient to justify the conclusion that the Nosema infection in a colony tends to weaken it. The weakness resulting does not occur immediately following the infection, however. During the active brood-rearing season the young bees reared may exceed the loss from disease and the colony will then actually gain in strength. On comparison of colonies that are infected with those that are not, however, it will be seen that the infected ones are the weaker. An experimental colony receiving repeated inoculations increases in strength, as a rule, during the first two weeks following the initial feeding through the emergence of young bees, but comparatively little, if any, after the first month.

The question arises as to whether the weakness is the result of infection in workers, drones, or the queen, or in a combination of these different members of the colony. Brood apparently does not become affected with *Nosema apis* (p. 10). The weakness in a colony can not be attributed, therefore, to infection of the brood. Infection among drones is rare (p. 11). Loss in strength, therefore, could not be expected to result from infection in the drones. The queen in an infected colony is more often free from the infection than not (p. 11). Weakness from Nosema infection can result, therefore, when the queen is free from infection. By elimination in this way the conclusion is reached that the weakness produced by Nosema infection in a colony is due primarily to infection among the adult workers.

Other observations made point to the same conclusion. Workers taken from colonies in which Nosema infection had reached a rather advanced stage were confined in the McIndoo wire-screen cages [1] and kept at room temperature. Healthy ones were similarly caged and kept under observation. The relative length of time that the infected and uninfected bees lived under these conditions was noted.

On December 8, 1914, in each of four cages were placed from 15 to 30 bees taken from colonies heavily infected with *Nosema apis*. By the end of one week, out of 79 bees confined 62 (78 per cent) had died. On the same date bees from another infected colony were similarly confined. At the end of a week out of 119 bees confined 108 (91 per cent) had died. On December 15, 1914, the experiments were

[1] Small triangular cages devised by McIndoo (1917, p. 4) in his studies on the honeybee.

repeated. Out of 138 bees in one set of four cages 125 (91 per cent) were dead at the end of one week. In the other set of four cages out of 136 bees confined 98 (72 per cent) were dead at the end of a week.

On December 8 a check experiment was begun. In each of two cages bees taken from healthy colonies were confined and kept at room temperature. At the end of one week out of 59 bees confined 5 (8 per cent) had died.

Out of a total of 472 diseased bees confined 393 (83 per cent) were dead at the end of one week, while out of a total of 59 healthy bees kept under similar conditions only 5 (8 per cent) were dead at the end of a week. Although such experiments are subject to great variation and should be repeated many times for definite results, yet the difference between 83 per cent of loss in the case of infected bees and 8 per cent of loss in the case of healthy ones is sufficiently great to justify the conclusion that the heavily infected bees under the conditions of the experiment possessed less endurance than the healthy ones. These results indicate that weakness in a colony may result directly from infection among the workers.

Throughout the investigations which have been made on the disease, therefore, evidence has been obtained indicating that weakness results not from the infection of the queen, drones, or brood, but of the workers.

RESISTANCE OF NOSEMA APIS TO HEATING.

NOSEMA APIS SUSPENDED IN WATER.

Preliminary results indicating the minimum amount of heating that is necessary to destroy *Nosema apis* were given in an earlier paper (White, 1914). Other experiments have been performed. In conducting the experiments a suspension was made in water of the crushed stomachs and intestines of Nosema-infected bees. This suspension was distributed in test tubes in such a dilution that the amount in each tube contained the infective material of from 5 to 10 bees. The tubes were stoppered and heated at different degrees of temperature by immersing them in water. Colonies free from infection were inoculated with the heated material and the results noted.

Table VI summarizes some of the experiments made with the results obtained.

TABLE VI.—*Experiments to determine the heat required to destroy Nosema apis suspended in water.*[1]

Date of inoculation.	Temperature employed.		Period of heating.	Results of inoculations.
	°C.	°F.	Minutes.	
Jan. 31, 1913	50	122	20	Nosema infection produced.
Jan. 8, 1913	55	131	10	Do.
Oct. 4, 1913	56	133	10	Do.
Oct. 15, 1913	56	133	10	Do.
May 21, 1915	58	136	10	Do.
Oct. 15, 1913	57	135	10	No infection produced.
Feb. 8, 1913	58	136	10	Do.
Oct. 4, 1913	58	136	10	Do.
Aug. 28, 1915	59	138	10	Do.
Nov. 11, 1912	60	140	10	Do.
Nov. 20, 1912	60	140	10	Do.
May 21, 1915	60	140	10	Do.
Aug. 28, 1915	61	142	10	Do.
Nov. 12, 1913	65	149	10	Do.
Jan. 8, 1913	65	149	10	Do.
Oct. 29, 1912	80	176	20	Do.
Nov. 12, 1912	100	212	5	Do.

[1] In omitting fractions of degrees the nearest whole number is given.

From Table VI it will be observed that *Nosema apis* in a water suspension was destroyed in 10 minutes at a temperature somewhere between 135° F. (57° C.) and 138° F. (59° C.).

NOSEMA APIS SUSPENDED IN HONEY.

From preliminary experiments it was learned that the amount of heating that is required to destroy *Nosema apis* suspended in glycerin is approximately equal to that required to destroy it when suspended in water. It was anticipated, therefore, that the minimum amount of heating that would destroy the germ suspended in honey would approximate that required to destroy it when suspended in water.

Experiments were made to determine the approximate thermal death point of *Nosema apis* when it is suspended in honey. In making the experiments the technique used was similar in the main to that of the preceding group of experiments wherein suspensions in water were heated. In Table VII are summarized the experiments performed, together with the results obtained.

TABLE VII.—*Experiments to determine the heat required to destroy Nosema apis suspended in honey.*

Date of inoculation.	Temperature employed.		Period of heating.	Results of inoculations.
	°C.	°F.	Minutes.	
Aug. 28, 1915	58	136	10	Nosema infection produced.
Aug. 27, 1915	59	138	10	Do.
June 9, 1915	59	138	10	No infection produced.
May 21, 1915	60	140	10	Do.
June 8, 1915	61	142	10	Do.
Aug. 28, 1915	61	142	10	Do.
June 9, 1915	62	144	10	Do.
June 8, 1915	63	145	10	Do.
May 5, 1915	65	149	10	Do.
May 21, 1915	70	158	10	Do.
May 21, 1915	80	176	10	Do.

Table VII shows that *Nosema apis* in a honey suspension was destroyed by heating for 10 minutes at a temperature between 136° F. (58° C.) and 140° F. (60° C.), the death point being about 138° F. (59° C.).

RESISTANCE OF NOSEMA APIS TO DRYING.

In experiments relative to the effect of drying on *Nosema apis*, stomachs from Nosema-infected bees were crushed, and the crushed tissues were smeared on slides to the extent of a thin layer. The slides were placed in incubator, room, outdoor, and refrigerator temperatures, respectively. At different intervals after the preparation of the smears an aqueous suspension was made, germs from two slides representing the material from 5 to 20 bees being used. This was added to sirup and fed to a healthy colony. Whether or not the parasite had been destroyed was determined by the presence or absence of Nosema-infection in the colony following the inoculation with the sirup.

NOSEMA APIS DRYING AT INCUBATOR TEMPERATURE.

In Table VIII are summarized the experiments, together with the results obtained, in which the Nosema material was allowed to dry at incubator temperature.

TABLE VIII.—*Resistance of Nosema apis to drying at incubator temperature.*

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	*Days.*	
July 30, 1915	0	10	Nosema infection produced.
July 14, 1916	0	13	Do.
Oct. 5, 1914	0	14	Do.
July 21, 1915	0	18	Do.
July 29, 1916	0	15	No infection produced.
Sept. 11, 1914	0	21	Do.
Nov. 2, 1914	0	30	Do.
Sept. 29, 1914	0	40	Do.
Oct. 16, 1914	0	56	Do.
July 9, 1915	2	15	Do.
May 24, 1915	7	27	Do.
July 9, 1915	9	19	Do.

From Table VIII it will be seen that *Nosema apis* drying at incubator temperature was destroyed in from 15 to 21 days, that is, during the third week.

NOSEMA APIS DRYING AT ROOM TEMPERATURE.

In Table IX are summarized experiments in which the drying of *Nosema apis* took place at room temperature.

TABLE IX.—*Resistance of Nosema apis to drying at room temperature.*

Date of inoculation.	Period of drying.	Results of inoculation.
	Days.	
July 26, 1916	18	Nosema infection produced.
Sept. 11, 1914	21	Do.
Aug. 11, 1916	35	Do.
Oct. 2, 1914	42	Do.
Sept. 1, 1915	43	Do.
Aug. 26, 1916	50	Do.
Oct. 16, 1914	56	Do.
May 24, 1916	60	No infection produced.
Sept. 1, 1915	61	Do.
June 27, 1916	95	Do.

From results recorded in Table IX it will be observed that *Nosema apis* drying at room temperature remained virulent for from 56 to 60 days, that is, about 2 months.

NOSEMA APIS DRYING AT OUTDOOR TEMPERATURE.

Table X summarizes experiments in which *Nosema apis* was allowed to dry at outdoor temperature.

TABLE X.—*Resistance of Nosema apis to drying at outdoor temperature.*

Date of inoculation.	Period of drying.		Results of inoculation.
	Months.	*Days.*	
Sept. 11, 1914	0	21	Nosema infection produced.
Oct. 2, 1914	0	42	Do.
Aug. 17, 1914	0	46	Do.
Oct. 16, 1914	0	56	Do.
June 7, 1916	0	60	Do.
Sept. 27, 1913	0	60	No infection produced.
July 9, 1915	0	75	Do.
June 27, 1916	0	80	Do.
Aug. 17, 1915	0	85	Do.
July 17, 1916	0	100	Do.
May 25, 1915	9	0	Do.
July 17, 1914	10	10	Do.
July 1, 1914	11	0	Do.

The results recorded in Table X show that *Nosema apis* ceased to be virulent after 2 months of drying at outdoor temperature.

NOSEMA APIS DRYING AT REFRIGERATOR TEMPERATURE.

Table XI summarizes experiments in which *Nosema apis* was allowed to remain dry in the refrigerator.

TABLE XI.—*Resistance of Nosema apis to drying at refrigerator temperature.*[1]

Date of inoculation.	Period of drying.	Results of inoculation.
	Months.	
Dec. 2, 1915	3	Nosema infection produced.
Jan. 3, 1916	4	Do.
Mar. 3, 1916	6	Do.
Apr. 2, 1916	7	Do.
Apr. 22, 1916	7½	No infection produced.
May 3, 1916	8	Do.
July 3, 1916	10	Do.

[1] A few times during the experiments in which the refrigerator temperature was used, the ice became exhausted, allowing the temperature to approach and possibly to reach that of the room. This higher temperature, when present, however, at no time prevailed for more than a day.

It is learned from the results recorded in Table XI that *Nosema apis* drying at refrigerator temperature remained virulent for seven months but that no disease was produced following inoculation with the material after seven and one-half months drying.

From the results obtained in the experiments relative to the resistance of *Nosema apis* to drying, given in Tables VIII–XI, it will be observed that the period the parasite remained alive, or at least virulent, varied, depending upon the environment of the germ. The shortest period for the destruction of spores was obtained under incubator conditions, while the longest period occurred under refrigerator conditions. The death probably was not due to the drying alone but to a combination of factors of which drying was an important one.

RESISTANCE OF NOSEMA APIS TO FERMENTATION.

Experiments have been made to obtain data relative to the resistance of *Nosema apis* to fermentative processes. In conducting the experiments suspensions of the crushed stomachs from Nosema-infected bees were made in a 10 per cent sugar (saccharose) solution and in a 20 per cent honey solution. These solutions were distributed in test tubes. Each tube contained infectious material equal to that present in the stomachs of from 5 to 10 infected bees. To each suspension was added a bit of soil to inoculate it further. Suspensions were allowed to ferment at incubator, room, outdoor, and refrigerator temperatures, respectively. At intervals reckoned in days the fermenting suspension from a single tube was transferred to about one-half pint of sugar sirup and fed to a colony free from the infection. The results were then noted.

FERMENTATION AT INCUBATOR TEMPERATURE.

In Table XII are summarized some of the results that were obtained when a suspension of *Nosema apis* in a 20 per cent aqueous solution of honey was allowed to ferment at incubator temperature.

TABLE XII.—*Resistance of Nosema apis to fermentation in a honey solution.*

Date of inoculation.	Period of fermentation.	Results of inoculation.
	Days.	
July 25, 1916	1	Nosema infection produced.
July 26, 1916	2	Do.
July 27, 1916	3	No infection produced.
July 28, 1915	4	Do.
July 12, 1915	5	Do.
July 15, 1916	8	Do.
July 17, 1916	10	Do.

From experiments recorded in Table XII it was shown that *Nosema apis* was destroyed by fermentation in 20 per cent honey solution at incubator temperature in three days.

FERMENTATION AT ROOM TEMPERATURE.

In Table XIII are summarized experiments in which colonies were inoculated with a suspension of *Nosema apis* in a 10 per cent sugar (saccharose) solution, which had been allowed to ferment, at room temperature.

TABLE XIII.—*Resistance of Nosema apis to fermentation in sugar solution at room temperature.*

Date of inoculation.	Time of fermentation.		Results of inoculation.
	Months.	*Days.*	
Sept. 8, 1915	0	5	Nosema infection produced.
Sept. 9, 1915	0	6	Do.
June 4, 1915	0	11	No infection produced.
Sept. 10, 1915	0	7	Do.
July 27, 1915	0	8	Do.
July 29, 1915	0	10	Do.
Sept. 13, 1915	0	10	Do.
Sept. 15, 1915	0	12	Do.
Sept. 16, 1915	0	13	Do.
Sept. 1, 1915	0	14	Do.
Jan. 9, 1915	0	18	Do.
Sept. 15, 1914	0	21	Do.
Sept. 29, 1914	0	34	Do.
June 9, 1914	7	12	Do.
June 10, 1914	10	6	Do.
May 13, 1915	18	6	Do.

From Table XIII it will be seen that the parasite was destroyed by fermentation in a 10 per cent sugar solution at room temperature in from 7 to 11 days. The range of variation shown may be attributed largely to variation in the temperature.

FERMENTATION AT OUTDOOR TEMPERATURE.

In Table XIV are summarized experiments made for the purpose of obtaining approximate data relative to the resistance of *Nosema apis* in a 20 per cent honey solution at outdoor temperature.

TABLE XIV.—*Resistance of Nosema apis to fermentation in a honey solution at outdoor temperature.*

Date of inoculation.	Period of fermentation.	Results of inoculation.
	Days.	
July 26, 1916	2	Nosema infection produced.
July 27, 1916	3	Do.
July 28, 1916	4	Do.
Sept. 8, 1915	5	Do.
July 29, 1916	5	Do.
Aug. 30, 1916	6	Do.
July 29, 1916	7	Do.
Aug. 31, 1916	7	Do.
Sept. 2, 1916	9	No infection produced.
Sept. 6, 1916	12	Do.

From Table XIV it will be observed that the parasite was destroyed in 9 days in the presence of fermentation processes taking place in a 20 per cent honey solution at outdoor temperature.

At refrigerator temperature it was found that *Nosema apis* resisted fermentative processes for more than seven and less than nine days.

It will be observed from the results obtained that *Nosema apis* in the presence of fermentative processes is destroyed in a comparatively short time. The period, it will be seen, varies somewhat with the temperature of the fermenting suspension. The experiments tend to indicate, furthermore, that the time element depends slightly upon the nature of the fermenting medium, the germ being destroyed sooner in a honey solution than in a saccharose one. The time element is dependent also upon the strength of the solutions employed.

RESISTANCE OF NOSEMA APIS TO PUTREFACTION.

Experiments have been made for the purpose of obtaining results relative to the resistance possessed by *Nosema apis* to putrefactive processes. The nature of the experiments was similar to those relative to fermentation but instead of sugar solutions used for the suspensions a 1 per cent peptone solution in water was employed. In the experiments, suspensions, after undergoing putrefactive changes at incubator, room, outdoor, and refrigerator temperatures, respectively, were used in the inoculation of colonies.

PUTREFACTION AT INCUBATOR TEMPERATURE.

The experiments summarized in Table XV indicate the resistance of *Nosema apis* to putrefaction at incubator temperature.

TABLE XV.—*Resistance of Nosema apis to putrefaction at incubator temperature.*

Date of inoculation.	Period of putrefaction.	Results of inoculations.
	Days.	
July 25, 1916	1	Nosema infection produced.
July 26, 1916	2	Do.
July 27, 1916	3	Do.
July 28, 1916	4	Do.
July 12, 1916	5	No infection produced.
Sept. 10, 1915	7	Do.
July 15, 1916	8	Do.
July 17, 1916	10	Do.

By the results recorded in Table XV it is shown that *Nosema apis* was destroyed by putrefaction at incubator temperature in five days.

PUTREFACTION AT ROOM TEMPERATURE.

In Table XVI are summarized experiments in which the putrefactive processes took place at room temperature.

TABLE XVI.—*Resistance of Nosema apis to putrefaction at room temperature.*

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	Days.	
July 28, 1915	12	Nosema infection produced.
July 21, 1915	18	No infection produced.
July 28, 1915	25	Do.
Sept. 29, 1914	34	Do.
July 1, 1915	40	Do.
Aug. 20, 1914	52	Do.

From Table XVI it is seen that *Nosema apis* at room temperature resisted the putrefactive processes for about two weeks. As the room temperature varies it is to be expected that the time required for the destruction of the parasite will vary also.

PUTREFACTION AT OUTDOOR TEMPERATURE.

The following table summarizes experiments that indicate the period *Nosema apis* resists putrefaction at outdoor temperature:

TABLE XVII.—*Resistance of Nosema apis to putrefaction at outdoor temperature.*

Date of inoculation.	Period of putrefaction.	Results of inoculation.
	Days.	
July 26, 1916	2	Nosema infection produced.
July 27, 1916	3	Do.
July 28, 1916	4	Do.
July 29, 1916	5	Do.
Aug. 31, 1916	7	Do.
Sept. 2, 1916	9	Do.
Sept. 6, 1916	12	Do.
Aug. 26, 1916	15	Do.
Sept. 2, 1916	22	Do.

In the experiments recorded in Table XVII it will be observed that *Nosema apis* was not destroyed in the presence of putrefactive changes at outdoor temperature in 22 days.

At refrigerator temperature the parasite has resisted putrefaction for more than three months.

The foregoing experiments relative to the effect of putrefactive processes on *Nosema apis* show that the parasite may be destroyed as a result of putrefaction. They show also that the temperature of the suspension is a factor in determining the period of resistance. Furthermore, it is seen that the germ resists the destructive processes accompanying putrefaction longer than those accompanying fermentation.

RESISTANCE OF NOSEMA APIS TO DIRECT SUNLIGHT.

RESISTANCE WHEN DRY.

Petri dishes (fig. 6) which were smeared with the crushed stomachs of Nosema-infected bees were exposed to the direct rays of the sun.

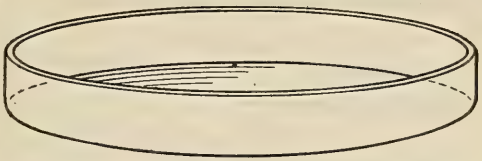


FIG. 6.—Open Petri dish. One-half of the dish, either top or bottom.

After intervals reckoned in hours healthy colonies were inoculated with a suspension made from the dishes which had been exposed. Table XVIII summarizes the experiments and the results obtained.

TABLE XVIII.—*Resistance of Nosema apis when dry to direct sunlight.*

Date of inoculation.	Period of exposure to sun.	Results of inoculation.
	Hours.	
Aug. 2, 1915	2	Nosema infection produced.
Aug. 21, 1914	5	Do.
Aug. 2, 1915	5	Do.
July 28, 1915	8	Do.
Aug. 27, 1914	10	Do.
Aug. 23, 1915	13	Do.
Aug. 20, 1915	15	Do.
Sept. 2, 1914	15	Do.
Aug. 25, 1915	17	Do.
Sept. 3, 1914	20	Do.
Sept. 14, 1915	29	Do.
Aug. 17, 1915	15	No infection produced.
Sept. 10, 1915	17	Do.
Aug. 19, 1915	18	Do.
Sept. 11, 1915	21	Do.
Aug. 24, 1914	22	Do.
Sept. 13, 1915	32	Do.
Aug. 4, 1914	34	Do.
Sept. 16, 1915	35	Do.

The results in Table XVIII show that *Nosema apis* was destroyed in the experiments recorded in from 15 to 32 hours' exposure to direct sunlight.

It will be readily appreciated that the time that *Nosema apis* will resist the destructive effects of the sun's rays will vary largely according to the intensity of the rays, the heat present, and the thickness of the layer of infective material exposed.

DESTRUCTION IN WATER.

In experiments made for the purpose of determining the time required to destroy *Nosema apis* suspended in water, an aqueous suspension of the crushed stomachs of about 10 bees was poured into each of a number of Petri dishes (fig. 6) and exposed to the direct

rays of the sun. The top of the dish was not on during the exposure. After intervals reckoned in hours inoculations were made of healthy colonies, the germs contained in one dish being used.

Table XIX gives a summary of a set of experiments of this kind.

TABLE XIX.—*Resistance of Nosema apis suspended in water to the direct rays of the sun.*

Date of inoculation.	Period of exposure.	Results of inoculation.
	Hours.	
Aug. 2, 1915	2	Nosema infection produced.
July 27, 1915	10	Do.
Aug. 20, 1915	12	Do.
Do	18	Do.
Aug. 26, 1915	20	Do.
Sept. 10, 1915	20	Do.
Aug. 27, 1915	27	Do.
Sept. 11, 1914	27	Do.
Sept. 13, 1915	44	Do.
Do	37	No infection produced.
Sept. 14, 1915	51	Do.
Sept. 16, 1915	58	Do.
Do	65	Do.
Sept. 17, 1915	72	Do.

The results in the foregoing table show that *Nosema apis* was destroyed by the direct rays of the sun in from 37 to 51 hours. It is seen, therefore, that *Nosema apis* when suspended in water shows a considerable amount of resistance. In the question of the transmission of the disease this resistance may be of considerable importance.

At the time these experiments were made the intensity of the rays was, as a rule, quite marked and, therefore, favorable for the destruction of germs. The temperature of the aqueous suspension, however, did not reach 136° F. (58° C.) and, therefore, was not sufficient to destroy the virus through heating. Some of the suspensions stood for more than a week in the Petri dishes, thereby introducing the factors of fermentation and putrefaction. The effect of these factors on the results is not known.

DESTRUCTION IN HONEY.

In performing the experiments crushed stomachs from about 10 Nosema-infected bees were suspended in about 3 ounces of honey in Petri dishes (fig. 7). To prevent robbing by bees the dish was used with the top on. The suspension was exposed to the direct rays of the sun with the dishes resting on a wooden support. After different intervals healthy colonies were inoculated with germs which had been exposed to the sun.

Even when resting on a wooden support it is not unusual during the summer for the honey of the suspension exposed to the sun to reach a temperature beyond the thermal death point of the parasite. To determine facts in regard to the effect of the sun's rays on *Nosema apis*, therefore, this point in regard to heat must be met by the technique employed. This could have been done quite easily but for the lack of time.

In the experiments it was found that *Nosema apis* was destroyed in all instances in which the temperature of the honey reached or exceeded 140° F. (60° C.), a temperature at which the germ is killed by heat (p. 30). Sufficient data, therefore, have not been obtained to warrant a definite conclusion regarding the time required for the

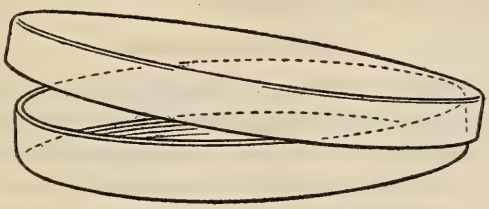


FIG. 7.—Petri dish. The top half is slightly raised. Those used here are 4 inches in diameter.

direct sunlight to destroy *Nosema apis* suspended in honey. The results obtained from the experiments made in which aqueous suspensions were exposed to the sun give some idea as to the probable approximate time which would be required.

PERIOD NOSEMA APIS REMAINS VIRULENT.

PERIOD IN HONEY.

In experiments made to determine the length of time *Nosema apis* remains virulent in honey a suspension of the parasite in honey was distributed in flasks, about one-half pint being poured into each flask. These were placed at room temperature and shielded from the light. After different intervals colonies were inoculated, the suspension from a single flask being used. The results obtained are included in Table XX.

TABLE XX.—*Period Nosema apis remains virulent in honey.*

Date of inoculation.	Period in honey.		Results of inoculation.
	Months.	*Days.*	
Oct. 20, 1914	1	0	Nosema infection produced.
Feb. 4, 1915	1	18	Do.
Feb. 24, 1915	2	0	Do.
Feb. 4, 1915	3	10	Do.
Jan. 16, 1915	3	27	Do.
July 14, 1915	2	6	No infection produced.
July 23, 1915	2	15	Do.
Oct. 21, 1915	2	25	Do.
June 11, 1915	3	5	Do.
Sept. 3, 1915	3	17	Do.
June 24, 1915	3	20	Do.
Oct. 21, 1915	3	21	Do.
July 24, 1916	4	4	Do.
Aug. 14, 1913	5	0	Do.
May 1, 1915	7	17	Do.
June 9, 1914	7	19	Do.
Apr. 27, 1915	9	7	Do.
May 5, 1914	9	19	Do.
July 26, 1916	12	0	Do.

The experiments summarized in Table XX show from the results recorded that *Nosema apis*, when suspended in honey and kept at room temperature, shielded from the light, remained virulent for from 66 to 124 days, that is, from 2 to 4 months. The wide variation noted here probably is due very largely to the variation in temperature of the honey suspension.

PERIOD IN DEAD BEES.

Among the factors tending to destroy *Nosema apis* within the remains of dead bees are drying, putrefaction, and probably fermentation. The temperature also is to be expected to vary the period of resistance. In conducting the experiments, therefore, incubator, room, outdoor, and refrigerator temperatures were used. Infected bees were killed and kept in these different environments. After different intervals suspensions were made in sirup, the crushed bodies of from 5 to 10 of the infected bees being used. Colonies were inoculated with the suspensions.

AT INCUBATOR TEMPERATURE.

Table XXI summarizes the results obtained when inoculations were made with suspensions of Nosema-infected material from bodies of bees kept at incubator temperature.

TABLE XXI.—*Resistance of Nosema apis within dead bees at incubator temperature (37.5° C.).*

Date of inoculation.	Period of drying.	Results of inoculation.
	Days.	
Apr. 9, 1916	2	Nosema infection produced.
Apr. 12, 1916	4	Do.
Apr. 14, 1916	6	Do.
June 27, 1916	7	No infection produced.
July 1, 1916	12	Do.
May 17, 1916	15	Do.
Aug. 4, 1915	16	Do.
Oct. 8, 1914	18	Do.
Aug. 8, 1915	21	Do.
Aug. 17, 1915	28	Do.
Oct. 19, 1915	30	Do.
Aug. 23, 1915	35	Do.
Aug. 6, 1914	38	Do.
Nov. 2, 1914	42	Do.

By the results recorded in the experiments summarized in Table XXI, it was shown that *Nosema apis* in the bodies of dead bees kept at incubator temperature ceased to be virulent in less than one week.

AT ROOM TEMPERATURE.

In Table XXII are summarized the experiments in which dead bees, kept at room temperature, furnished the Nosema-infected material for the suspensions used in the inoculations.

TABLE XXII.—*Resistance of Nosema apis in dead bees kept at room temperature.*

Date of inoculation.	Period of drying.	Results of inoculation.
	Days.	
Aug. 4, 1915	16	Nosema infection produced.
Aug. 10, 1915	21	Do.
July 17, 1916	28	Do.
Aug. 26, 1916	30	Do.
Aug. 17, 1916	28	No infection produced.
June 3, 1916	32	Do.
Aug. 23, 1915	35	Do.
July 26, 1916	36	Do.
Aug. 1, 1916	43	Do.
June 27, 1916	56	Do.
Aug. 20, 1914	111	Do.
Aug. 30, 1914	168	Do.

From Table XXII it is learned that when dead infected bees were kept at room temperature the parasite remained virulent for three or four weeks, but did not produce the disease after one month. Since the temperature of the room was not constant, variations in results obtained at this temperature are to be expected.

AT OUTDOOR TEMPERATURE.

Dead Nosema-infected bees were placed in a hive body standing in the experimental apiary. At different intervals suspensions were made and colonies were inoculated. In Table XXIII are summarized a few experiments indicating by the results obtained the approximate period *Nosema apis* remains virulent in the body of dead bees at outdoor temperature.

TABLE XXIII.—*Resistance of Nosema apis in dead bees drying at outdoor temperature.*

Date of inoculation.	Period of drying.	Results of inoculation.
	Days.	
Oct. 19, 1914	28	Nosema infection produced.
Aug. 23, 1915	35	Do.
Nov. 2, 1914	42	Do.
June 7, 1916	36	No infection produced.
June 27, 1916	56	Do.
July 17, 1916	76	Do.

From Table XXIII it is seen that *Nosema apis* in the bodies of dead infected bees kept dry at outdoor temperature remained virulent for from five to six weeks. These experiments extended over a period from June to November, as shown by the dates. It is to be expected that if they had been conducted throughout the year the results obtained would have shown a much wider range of variation.

AT REFRIGERATOR TEMPERATURE.

In Table XXIV are summarized experiments the results of which indicate the approximate period during which *Nosema apis* remains virulent in the bodies of infected bees kept at refrigerator temperature.

TABLE XXIV.—*Resistance of Nosema apis in dead bees drying at refrigerator temperature.*

Date of inoculation.	Period in refrigerator.	Results of inoculation.
	Months.	
Mar. 4, 1916	2	Nosema infection produced.
Mar. 20, 1916	2	Do.
Mar. 20, 1916	2½	Do.
Apr. 22, 1916	3	Do.
May 6, 1916	3½	Do.
Dec. 7, 1915	3	No infection produced.
Jan. 7, 1916	4	Do.
May 24, 1916	4	Do.
June 3, 1916	4	Do.
Feb. 10, 1916	5	Do.
Apr. 7, 1916	6	Do.
May 6, 1916	8	Do.
July 3, 1916	10	Do.

The results recorded in Table XXIV show that *Nosema apis* in the bodies of dead infected bees remained virulent at refrigerator temperature from two and a half to four months.

ON THE SOIL.

Dead Nosema-infected bees were placed on the soil in the open, but in a somewhat shaded spot. After different intervals of time colonies were inoculated, these dead bees being used as the source for the infective material. Table XXV summarizes the experiments performed, the results of which indicate the approximate period during which *Nosema apis* remains virulent in the bodies of dead bees lying on the soil.

TABLE XXV.—*Resistance of Nosema apis in dead bees lying on the soil.*

Date of inoculation.	Period on soil.	Results of inoculation.
	Days.	
July 16, 1915	13	Nosema infection produced.
Aug. 1, 1916	18	Do.
Aug. 23, 1915	25	Do.
Aug. 12, 1916	29	Do.
Aug. 26, 1916	43	Do.
Aug. 28, 1915	44	Do.
May 14, 1916	71	No infection produced.
Oct. 4, 1915	77	Do.
Oct. 21, 1915	85	Do.
Oct. 21, 1915	94	Do.
Oct. 4, 1915	104	Do.
Nov. 9, 1915	104	Do.

From the results recorded in Table XXV it is seen that when the dead Nosema-infected bees were allowed to remain on the soil exposed to outdoor conditions *Nosema apis* was virulent at the end of 44 days, but the germ had lost its virulence before 71 days. Results of experiments having the nature of those referred to in this table naturally depend largely upon the climatic conditions which prevail.

It was observed that insects, ants especially, fed upon the dead bees lying on the ground. In this way they removed much of the material containing the parasites. This fact must be borne in mind in a consideration of the length of time that bees dead of Nosema disease and lying on the soil might serve as a possible source of infection.

The five foregoing groups of experiments relative to the period during which *Nosema apis* remains virulent in the bodies of dead infected bees show that the period varies with the environment under which the bees are kept, the temperature being an important factor in causing the variation. It is interesting to note that under fairly favorable conditions for its preservation *Nosema apis* remains virulent within the bodies of dead infected bees only three months, while under less favorable conditions its destruction occurs in a much shorter period.

INFECTIOUSNESS OF BROOD-COMBS FROM NOSEMA-INFECTED COLONIES.

Experiments have been made for the purpose of obtaining data relative to the likelihood of the transmission of Nosema disease from colony to colony through the medium of brood-combs. Brood-combs on which colonies had died of the disease and others taken from colonies heavily infected with *Nosema apis* through experimental inoculation were inserted into healthy colonies after different periods of time had elapsed following their removal. Table XXVI gives a summary of experiments made and the results obtained.

TABLE XXVI.—*Results from insertion of brood-combs from Nosema-infected colonies into healthy ones.*

Date combs were inserted.	Period combs were stored.	Number of combs inserted.	Results of inoculation.
Apr. 20, 1915	Inserted immediately.	4	No Nosema infection produced.
Do	do	3	Do.
Apr. 26, 1915	do	3	Do.
July 3, 1915	do	3	Do.
May 19, 1916		1	Do.
Apr. 26, 1915	¼ month	3	Do.
Do	do	3	Do.
Apr. 24, 1915	1 month	2	Do.
June 18, 1914	2 months	2	Do.
June 29, 1914	do	2	Do.
Apr. 24, 1915	3 months	2	Do.
May 1, 1915	do	2	Do.
Aug. 22, 1914	4 months	2	Do.
May 19, 1916	6 months	1	Do.

As will be observed from Table XXVI, infection did not occur in any of the experiments in which brood-combs from Nosema-infected colonies were given to healthy ones. The practical import of the results is that brood-combs from Nosema-infected colonies need not be destroyed, but may be inserted without treatment into hives containing healthy bees with practically no fear that losses will result from such manipulation. (See also experiment No. 2, p. 25.)

RESISTANCE OF NOSEMA APIS TO CARBOLIC ACID.

Stomachs taken from Nosema-infected bees were crushed and suspended in aqueous solutions of carbolic acid (commercial). One, 2, and 4 per cent solutions were used. These suspensions, respectively, were distributed in test tubes and were allowed to stand at room temperature. After different intervals healthy colonies were inoculated, the suspension from a single tube being used for each.

A summary of experiments performed with the results obtained is given in Table XXVII.

TABLE XXVII.—*Effect of carbolic acid on Nosema apis.*

Date of inoculation.	Per cent of carbolic-acid solution.	Period in carbolic acid.		Results of inoculation.
		Hours.	*Minutes.*	
Aug. 18, 1915	1	0	10	No infection produced.
July 16, 1915	1	1	0	Do.
July 2, 1915	1	6	0	Do.
June 9, 1915	1	51	0	Do.
Aug. 18, 1915	2	0	10	Do.
July 16, 1915	2	1	0	Do.
July 2, 1915	2	6	0	Do.
June 8, 1915	2	27	0	Do.
July 16, 1915	4	1	0	Do.
July 2, 1915	4	5	0	Do.
June 8, 1915	4	27	0	Do.

From the preliminary results given in Table XXVII it will be noted that *Nosema apis* is rapidly destroyed in 1, 2, and 4 per cent aqueous solutions, respectively, of carbolic acid, showing that the parasite possesses very slight resistance to the disinfectant.

EFFECT OF DRUGS ON NOSEMA-DISEASE.

It is natural that beekeepers should have thought of drugs and employ them in the treatment of Nosema infection. Preliminary experiments have been made to obtain data relative to the effect of betanaphthol, salol (phenyl salicylate), carbolic acid (phenol), salicylic acid, formic acid, oil of eucalyptus, and quinin (bisulphate of quinin) on this infection. It will be recalled that most of these drugs have been given a trial from time to time by beekeepers in the treatment of one or more of the bee diseases.

In the experiments honey was diluted with an equal quantity of water and medicated.[1] To the medicated solution *Nosema apis* was added. This suspension was fed to a colony, usually within a half hour from the time it was made. On each of four or five days immediately following the inoculation, the colony was fed honey medicated with the drug but free from *Nosema apis*.

In Table XXVIII are summarized the experiments performed, together with the results obtained.

TABLE XXVIII.—*Effect of drugs on Nosema infection.*

Drug.	Experiment 1.		Experiment 2.		Experiment 3.		Experiment 4.	
	Proportion.	Results.	Proportion.	Results.	Proportion.	Results.	Proportion.	Results.
Betanaphthol	2:1,000	No infection.	1: 1,000	No infection.	1: 2,000	No infection.	1: 5,000	Infection.
Salol	2: 1,000	...do	1: 1,000	...do	1: 2,000	...do	1: 5,000	Do.
Salicylic acid	2: 1,000	...do	1: 1,000	...do	1: 2,000	Infection.	1: 5,000	Do.
Carbolic acid	3: 1,000	...do	2: 1,000	...do	1: 1,000	...do		
Formic acid	3: 1,000	...do	2: 1,000	...do	1: 1,000	...do		
Eucalyptus	5: 1,000	Infection.	4: 1,000	Infection.	2: 1,000	...do		
Quinin	10: 1,000	...do	4: 1,000	...do	2: 1,000	...do		

The results recorded in Table XXVIII show that the parasite was destroyed by some of the drugs used but that it resisted others. Their relative efficiency as indicated from these preliminary results is shown by the arrangement in the table. Betanaphthol and salol seem to be the most effective of those tried, and eucalyptus and quinin the least efficient.

Experiments were performed in which the inoculation with *Nosema apis* was not followed by feedings with medicated sirup. The results obtained show that under the conditions of the experiments the drugs affected the parasite as seen by the lower percentage of Nosema-infected bees in the colonies inoculated. In colonies receiving subsequent feedings of medicated sirup a still lower percentage of infected bees was found.

While it is thus established that *Nosema apis* is somewhat susceptible to the effects of some of the drugs, the experiments are altogether too few for definite conclusions as to the extent of their action. Statements regarding the effect of the drugs on Nosema-disease, therefore, should be accepted cautiously, for the present at least, unless they are supported by experimental or other good evidence.

[1] In obtaining the desired proportion of the drug, betanaphthol, salol, salicylic acid, and eucalyptus were dissolved in alcohol. In the case of carbolic acid, formic acid, and the bisulphate of quinin aqueous solutions of the drugs were employed.

MODES OF TRANSMISSION OF NOSEMA-DISEASE.

No problem in the study of Nosema-disease is more important than that of its transmission. The problem is at the same time one of the most difficult for complete solution. While further information is still much desired, yet it is possible from the studies which have been made to arrive at certain conclusions concerning the manner in which the disease is spread. The discussions which follow are based chiefly upon observations noted in the foregoing pages.

It is naturally safe to conclude that the transmission of Nosema-disease depends directly upon the transmission of the parasite that causes it. If the course of *Nosema apis* in nature were followed completely, therefore, the problem relative to the spread of the disease would be solved. Such a task is difficult, as the possible sources for the parasite and the accompanying conditions are various.

The fact, determined experimentally, that a suspension of *Nosema apis* in sirup when fed to bees will produce the disease shows quite conclusively that infection takes place through the ingestion of the parasite. At present there is no evidence that it takes place otherwise than by way of the alimentary tract. This leads to the important tentative conclusion that the transmission of the disease is effected through either the food or the water supply of bees, or both.

On reaching the stomach by ingestion the parasite begins its growth, invades the walls of the organ, multiplies enormously, and forms spores which are shed into the lumen and passed out of the alimentary tract with the excrement. The chances that any single parasite once outside the bee will be ingested and cause infection are very slight. The immense number that are produced, however, increases the chances very greatly. Again, the chances of infection are very much reduced by the many destructive agencies in nature encountered by the parasite. Among these are drying (p. 31), heat (p. 29), direct sunlight (p. 37), fermentation (p. 33), and putrefaction (p. 35).

The excrement is voided normally during flight and most often soon after the bee leaves the hive. Should the droppings from infected bees fall into a body of water, such water would become thereby contaminated with the Nosema parasite and the use of it by bees would expose them to infection. Should the body of water be a rapidly flowing one, naturally the chances that other colonies of the apiary might become infected from such a source would be less than if it were a sluggish one. Should such contaminated water be exposed to the sun, the rays of the latter would have a tendency to destroy the parasites. The resistance of *Nosema apis* to the destructive effects of the sun's rays (p. 38) are sufficiently great, however, that there would still remain a strong likelihood that infection might take place from the water supply. While in the water

the parasites may be subjected to fermentation or putrefaction or both. These factors would tend to destroy the germ, although its resistance under these conditions is again considerable.

It has been suggested by some writers that drops of water from showers or dew on vegetation about the apiary might become contaminated by excrement present and thus be a source of infection. This would seem to be a possibility. The extent, if any, to which the disease is thus transmitted is not yet known.

Should the excrement of infected bees fall on the soil, the chances, ordinarily, would be slight that the contained parasite would reach a bee and infect it. Should the surface water resulting from rains carry the germ into a water supply used by bees, the chances of infection from the soil as a source would be considerably increased thereby. If the bodies of dead Nosema-infected bees were washed into the water supply, contamination of it might follow.

In estimating the probable danger of infection from the bodies of bees dead of Nosema-disease, the possibility of the parasites being destroyed after the death of such bees through putrefaction (p. 35), drying (p. 31), or other means must be given due consideration.

The facts which are known concerning Nosema-disease indicate that the disease may be transmitted: (1) From the infected bees of a colony to healthy bees of the same colony, and (2) from the infected bees of a colony to healthy bees of another colony. When the infection is transmitted from infected bees to noninfected ones of the same colony, the question arises as to whether such infection takes place while the bees are within or without the hive. The fact that the heaviest infection with *Nosema apis* occurs in the spring of the year, and the further fact that only a comparatively few colonies of the apiary are likely to be heavily infected, support the tentative conclusion that the transmission of the germ takes place within the hive rather than from a source outside of it.

There are facts concerning the disease, however, which indicate that the infection under certain circumstances is not readily transmitted within the hive. For example, colonies which in the spring of the year show less than 50 per cent of Nosema-infected bees are likely to recover from the infection without treatment, showing that under such circumstances the infection is not transmitted within the hive, to any great extent at least. The fact that a colony may contain a small percentage of Nosema-infected bees throughout the year and not become heavily infected at any time furnishes further evidence that Nosema infection does not always spread with rapidity within the hive. It has been found that colonies becoming heavily infected through experimental inoculation in June, July, or August, are practically free from the infection within six weeks from the date of inoculation, showing again that the infection is not always readily transmitted within the hive.

Colonies may die out, or they may only become weakened by the disease. Each of these conditions invites robbing, which in a certain number of cases probably results in the transmission of the disease. The likelihood of the transmission of the disease through robbing, however, seems to be not nearly as great as in the case of the foulbroods.

Uninoculated colonies in the experimental apiary have always remained practically free from infection, although colonies heavily infected as the result of experimental inoculations were present. This fact suggests that very little infection, if any, results either from the visit of healthy bees to flowers previously visited by infected ones, or, furthermore, from the straying or drifting of bees from infected to healthy colonies.

The possibility that the queen may be infected and that infection will be transmitted by her to the other bees of the colony need give the apiarist no uneasiness, and no concern need be felt that drones will spread the disease in the apiary.

Fear that Nosema-infection might be transmitted by hives which have housed infected colonies need not be entertained; neither is it to be feared that the hands or clothing of the beekeepers, or the tools used about an apiary, will serve as means for the transmission of the disease. Furthermore, the spread of the disease is not to be attributed directly to winds.

Theoretically it would seem that combs from Nosema-diseased colonies, if inserted into a healthy colony, would be the means of transmitting the disease and that the danger would extend over a period of a few weeks or months (p. 39). Experimentally it is shown, however, that such combs can be inserted immediately without transmitting the disorder, at least appreciably (p. 43).

Evidence is yet to be obtained to prove that insects other than honeybees are susceptible to infection with *Nosema apis*. A few experiments made in which silkworms, maggots, and ants were inoculated with this parasite gave negative results. At the present time, therefore, there is no cause for fear that Nosema-disease will be transmitted as the result of a similar infection in other insects.

DIAGNOSIS OF NOSEMA-DISEASE.

Nosema-disease usually can be diagnosed from the colony symptoms present together with the gross appearance of stomachs removed from adult bees of the colony.

Weakness, especially in the spring of the year, should cause a suspicion that the disease is present. The suspicion is strengthened if in such a colony the brood in general is normal, if the adult bees are not noticeably different in outward appearance or behavior from bees of healthy colonies, if the queen is present and if stores are abundant.

While the colony symptoms may justify a very strong suspicion that the disease is present, an examination of the stomachs from adult bees of the colony is necessary in making a definite diagnosis. The selection of the proper sample for examination is important. In choosing samples it is advisable to take such bees as are most likely to show a high percentage Nosema-infected. Young workers, old shiny ones, and drones are, therefore, to be avoided. Workers from the field are naturally to be preferred. As bees carrying pollen are most readily recognized as being field bees, these are the ones usually sought. Sometimes it is more convenient to take bees carrying honey or water. Next to the field bees, preference should be had for bees from among those about the entrance of the hive. During the colder seasons of the year it is often necessary to take the samples from the brood-combs.

Ten bees from a colony constitute a satisfactory sample as a rule. Ordinarily these are taken at the entrance with forceps. They are killed by pinching the thorax. All of the bees of the sample should be examined.

In removing the stomach for examination the bee is held by the thorax between the thumb and index finger of one hand and with a pair of forceps held in the other the tip of the abdomen is seized and pulled gently. By this method the organs of the alimentary tract (Pl. I) forward to and including the stomach are easily obtained. Occasionally the proventriculus and honey sac are also removed by this procedure. The stomach is the most prominent of the organs removed and the one that is most readily recognized.

If the stomach upon removal appears swollen and lighter in color than a healthy one, Nosema infection may be suspected; if it is chalk-white and easily torn, infection is very probable; should the tissues of the organ when crushed be milky in appearance, infection is practically certain. Usually the gross examination is sufficient for a definite diagnosis of the disease as encountered in nature. Sometimes it is desirable however, to have such a diagnosis confirmed by a microscopic examination of the crushed tissues of the stomach. This is often the case in experimental studies.

If infection is present in a bee the oval glistening spores of the parasite (fig. 4) usually will be found in very large numbers upon a microscopic examination of the crushed tissues of the stomach. No staining is needed. Addition of water to the mount is not necessary but it improves the preparation, permitting the spores to be seen more distinctly. Stomachs which become dry, after their removal and before the examination is made, can be used readily by the addition of water.

Very few objects are encountered in the microscopic examination of the stomachs that are likely to be mistaken for the spores of *Nosema apis*. Occasionally yeasts are encountered. They occur, however, in small numbers only, as a rule; a variation in size is usually to be observed; and if stained they take the stain readily and intensely. The writer occasionally has encountered small oval bodies resembling spores which escape from pollen grains. They are found in comparatively small numbers when encountered, however, and are smaller than Nosema spores. What these bodies are has not been determined.

In examining bees that have been dead of Nosema-disease for some time a portion of the contents of the abdomen is suspended in water on a slide and examined microscopically. The highly refractive oval spores of the parasite will be found if the bee was Nosema infected at the time of its death. Younger stages of the parasite will not be encountered under these conditions.

Stages of the parasite that precede that of the spores may be recognized at times from fresh preparations. Forms approaching spores in appearance, which have been referred to as young spores, together with growing or vegetative forms appearing frequently as though they were in pairs (Pl. III, I), are seen occasionally. These younger forms are not likely to be recognized in preparations except in those made from bees recently killed and then only in small numbers. They should not be depended upon in the making of the diagnosis.

To determine very early stages of infection with *Nosema apis* the stomach of the suspected bee must be fixed, sectioned, and stained by laboratory methods.[1] The parasite is then found in the epithelial cells of the organ.

Nosema-disease, like sacbrood, is quite prevalent among bees, and like sacbrood a small amount of infection may be present in a colony without producing any appreciable loss. When a diagnosis of the disease is being made in practical apiculture, therefore, considerable caution should be observed. A colony showing only a small percentage of Nosema-infected bees and no other evidence of the disease is practically healthy. In reporting the presence of infection it would seem well to indicate in some way the amount of infection present. The percentage of infected bees among those examined might be given.

[1] As a fixing fluid one containing a strong solution of mercuric chlorid can be recommended in studies on *Nosema apis*. Heidenhain's iron hematoxylin is a very satisfactory stain for much of the work. Other fixers, especially those containing picric acid or formalin, have been used successfully. The spores of *Nosema apis* are not readily stained by all stains. Pyronin sometimes gives good results with methyl green as a counterstain. Alcoholic eosin applied for a considerable period, with methyl blue as a counterstain, used on fixed smears made from fresh tissues, often results in desirable preparations.

In expressing a positive diagnosis the degree of infection could be indicated, for the present at least, by the terms "slight," "moderate," "heavy," and "very heavy." Slight infection by this scheme would indicate that not more than 10 per cent of the bees are infected and that no noticeable loss is to be anticipated from the infection; moderate infection would indicate that from 10 to 35 per cent are infected, that the colony will probably sustain losses from the disease, but that the chances are good for recovery; heavy infection would indicate that from 30 to 60 per cent are infected, that the colony will most likely show weakness as a result of the disease, and that it may or may not die; and very heavy infection would indicate that more than 60 per cent are infected and that the colony will probably die as a result of the disease.

While a definite diagnosis in regard to Nosema infection can always be made by laboratory methods (McCray and White, 1918), beekeepers in most instances can diagnose the disease sufficiently well for practical purposes in the apiary. Weakness should cause suspicion. If there is no other obvious cause for the weak condition a strengthened suspicion is justified. If, upon the removal of the stomachs of a few field bees (at least 10 should be examined), some white stomachs are found among them, the presence of Nosema-disease is quite certain. Should there still exist a doubt the organ should be examined further. If the tissues seem to tear easily and when crushed present a milky appearance,[1] it may be concluded that the colony is Nosema infected.

DIFFERENTIAL DIAGNOSIS.

Dysentery, paralysis, palsy, spring dwindling, Isle of Wight disease, May pest, May sickness, abdominal distension, dry dysentery, dropsy, and disappearing trick are some of the many names which have been applied to disorders among adult bees. The disorders for which the names have been used have not been sufficiently well defined in all instances, however, to insure their positive diagnosis. From the facts at hand it seems probable that the number of adult diseases is small and that each disease, therefore, from time to time has had more than one name applied to it. It seems equally probable that some of the names used have been applied to more than one disease.

Although little of a definite character is known concerning the disorders of adult bees in general, Nosema-disease is such a definite condition that its differentiation from other disorders should not be difficult. It is the only adult disease that can be diagnosed positively at the present time by laboratory methods.

[1] In testing the "milky appearance," crush the suspected stomach between two plates of clear glass.

DYSENTERY.

The term "dysentery" as applied to a disorder among adult bees is found in early beekeeping literature and is still encountered frequently. The spotting of the hive which is so often referred to as a symptom of dysentery and the absence of *Nosema apis* will serve to distinguish it from Nosema-disease.

PARALYSIS.[1]

The term "paralysis" has been widely used to designate a disease of adult bees. In this country the name usually is applied to a condition in which a large number of the bees of the affected colony die suddenly with the result that often a large mass of them is found in front of the hive. When this disorder is encountered usually only a colony here and there in the apiary is affected. Whether or not the disorder is infectious has not yet been determined. Time has permitted the making of only a few preliminary experiments on this disorder by the writer. The few which have been made and the facts as observed by practical beekeepers indicate that if the disease is infectious it is only slightly so. It is not likely, therefore, to spread to any great extent in the apiary. It can be differentiated from Nosema-disease by the absence of *Nosema apis* in the bees that have died of the disorder, and in the bees remaining in the colony.

SPRING DWINDLING.

It is very probable that more than one disorder has been referred to by the term "spring dwindling." When Nosema-disease was encountered by the beekeepers in the past, most likely it was often designated spring dwindling. Other conditions which are called spring dwindling may be differentiated from Nosema-disease by the fact that *Nosema apis* is present in Nosema-disease and is absent in other conditions unless, of course, a mixed infection is present.

ISLE OF WIGHT DISEASE.

There has been encountered in many parts of England a disorder among adult bees from which heavy losses have been reported. The condition was described in 1906 by the beekeepers on the Isle of Wight, where apiaries had suffered heavy losses.

Bullamore and Malden (1912), of England, after studying the symptoms of the disease, arrived at the conclusion "that no one symptom is characteristic of the Isle of Wight disease, the only essential feature being the death of large numbers of bees within or

[1] On account of the shaking or trembling movements sometimes manifested by individual bees affected, the term "palsy" has been used to designate the condition. As this term describes more accurately a marked symptom observed in the individual bee affected, it would seem to be a more appropriate one than "paralysis."

without the hive." They believed that the condition had been endemic in parts of England for many years, and shared with Graham-Smith the belief that a large amount of the losses among adult bees ascribed to it is due to Nosema infection.

From the facts at hand it is not possible to state whether the Isle of Wight disease and Nosema-disease are one and the same disorder. Studies made on the Isle of Wight disease by English workers will most likely result in revealing further valuable facts concerning it (Anderson and Rennie, 1916). The writer examined one sample of adult bees from England taken from a colony suffering from Isle of Wight disease. No spores of *Nosema apis* were found in the sample. The results of the examination naturally prove nothing regarding the disease.

For the present the American beekeeper should bear in mind that when Nosema-disease is given as the diagnosis, a condition having the destructiveness described for the Isle of Wight disease is not meant.

OTHER DISEASES OF ADULT BEES.

It is quite probable that other diseases of adult bees than those referred to here exist. If so, they have not yet been sufficiently studied to make their recognition possible, at least by laboratory methods. Such disorders could be differentiated from Nosema-disease by the absence in them of *Nosema apis*. As Nosema infection is very widely distributed among bees, the fact must always be borne in mind that Nosema infection may occur in a colony together with other bee diseases and be of secondary importance. This caution should never be overlooked.

PROGNOSIS IN NOSEMA-DISEASE.

The prognosis in Nosema-disease varies markedly and is dependent upon the conditions present. Of these conditions the percentage of Nosema-infected bees in the colony, the strength of the colony, the season of the year, and the environment of the apiary are among the more important factors which determine the outcome of the disease.

The percentage of Nosema-infected bees in the colony may be very small, much less than 1 per cent, or it may be very large, reaching practically 100 per cent. Between these limits all degrees of infection are encountered, the prognosis in each instance being different.

As a rule colonies which in the spring of the year show less than 10 per cent of Nosema-infected bees gain in strength and the losses are not detected. This is often true also in cases where the infection is somewhat greater than 10 per cent. When the number of infected bees approaches 50 per cent the colonies become noticeably weakened and in many instances death takes place. When more than 50 per

cent are infected they become weakened and usually die as a result of the infection. Generally speaking, therefore, it may be said that when a colony contains less than 10 per cent of Nosema-infected bees the prognosis is excellent; that when it contains more than 10 and less than 50 per cent the prognosis is fair; that when it contains more than 50 per cent the prognosis is unfavorable; and that when the number of Nosema-infected bees present approaches 100 per cent the prognosis is especially grave.

In arriving at a decision as to the probable course and outcome of the infection the strength of the colony must also be considered. This factor, indeed, may be the deciding one. As a rule, the stronger the colony, the more favorable is the prognosis.

In early spring heavy losses among the workers are not replaced and the colony weakens. During the active brood-rearing season, on the other hand, the bees dying of the infection are replaced by young bees. These young bees being free from infection and the transmission of the disease within the hive during summer being slight as a rule, the prognosis at this season of the year is favorable.

Experimentally it is found that a single inoculation early in the spring will cause a colony to die as a result of the infection produced; if inoculated somewhat later, however, the colony will weaken appreciably but will recover from the infection; if inoculated during the active brood-rearing season the weakening effect resulting from the infection may not be appreciable; if inoculated toward the close of the brood-rearing season the weakness resulting will be noticeable, but the colony may winter; and if inoculated later in the autumn or during the winter the colony will die as a result of the infection. It will be seen, therefore, that the prognosis in Nosema-disease in every case is dependent in some measure upon the season of the year, being more favorable in the active brood-rearing season than in any other. Indeed the season may play a major rôle in determining the course and outcome of the disease.

The immediate environment of the apiary may possibly play a rôle in determining the prognosis. Opportunity for reinfection from without tends to vary the course and outcome of the disease. In this connection the nature of the water supply should not be overlooked.

The extent to which the different races of bees vary in their susceptibility to the disease, the extent to which individual colonies vary in their susceptibility, and the extent to which different strains of *Nosema apis* vary as to their virulence are not at all definitely known at the present time. The facts, however, indicate that in no instance is the variation particularly great. Much care should be exercised, therefore, in ascribing variations in losses from the disease to the two phenomena virulence of the germ and resistance of the host.

Whether a bee once infected ever recovers from the infection has not yet been established definitely. From what is known of diseases in man and animals one might expect recovery in a certain percentage of Nosema-infected bees. The data at hand indicate that occasionally recovery does take place in the worker bee. This is suggested by the fact that among the last few workers alive in a colony, following a heavy infection resulting from an experimental inoculation, some have been found upon examination to be only slightly infected and still others to be free from infection. The only conclusion that can be drawn at the present time on this point is that if recovery from the infection ever takes place in the worker bee the cases are comparatively rare.

Whether the prognosis is as grave in the case of an infected queen is not known. The facts at hand suggest that it probably is not. In the writer's experience less than 50 per cent of the queens in experimental colonies were found to be infected (Table I). Whether they had been infected and had recovered was not determined. The queens from colonies which had been inoculated from one to three weeks were found to be free from infection, indicating that infection was infrequent, at least within the period that workers and drones show the greatest percentage of infection.

Death from Nosema infection does not take place for some time after infection. The length of time an infected worker lives depends in a large measure upon the season of the year. During the active bee season death takes place as a rule in less than one month but in more than two weeks. During winter the disease may run a course of two or three months or even more. Infected drones die sooner than infected workers, whereas infected queens probably live longer. This relation is to be expected since in healthy bees a somewhat similar relation exists. It is quite likely that the age of the bee when infected is not a negligible factor in determining the course of the disease.

Finally it should be emphasized that the prognosis of Nosema infection, as it occurs in the United States, is not nearly so unfavorable as has been reported for the Isle of Wight disease in England and for Nosema infection in Bavaria, Germany. It is, however, very similar to that of the infection as it has been reported from Australia (Price, 1910; Laidlow, 1911; and Beuhne, 1916).

SUMMARY AND CONCLUSIONS.

The following statements concerning Nosema-disease seem to be justified from the facts recorded in the present paper:

(1) Nosema-disease is an infectious disorder of adult bees caused by *Nosema apis*.

(2) The disease is not particularly malignant in character, being in this respect more like sacbrood than the foulbroods.

(3) Adult workers, drones, and queens are susceptible to infection, but the brood is not.

(4) The infecting agent *Nosema apis* is a protozoan that attacks the walls of the stomach and occasionally those of the Malpighian tubules.

(5) A colony can be inoculated by feeding it sirup containing the crushed stomachs of infected bees.

(6) One-tenth of the germs present in a single stomach are sufficient to produce marked infection in a colony.

(7) Within a week following the inoculation the parasite can be found within the walls of the stomach.

(8) Before the close of the second week infection can be determined by the gross appearance of the organ.

(9) The disease can be produced at any season of the year by feeding inoculations.

(10) Infected bees may be found at all seasons of the year, the highest percentage of infection occurring in the spring.

(11) Nosema infection among bees occurs at least in Australia, Switzerland, Germany, Denmark, England, Canada, and the United States. This distribution shows that the occurrence of the disease is not dependent altogether upon climatic conditions.

(12) The course of the disease is not affected directly by the character or quantity of food obtained and used by the bees.

(13) A sluggish body of water, if near an apiary and used by bees as a water supply, and the robbing of diseased colonies, must be considered for the present as two probable sources of infection.

(14) The transmission of the disease through the medium of flowers is not to be feared.

(15) The hands and clothing of the apiarist, the tools used about an apiary, and winds need not be feared as means by which the disease is spread.

(16) Hives which have housed infected colonies need not be disinfected and combs from such colonies are not a likely means for the transmission of the disease.

(17) Bees dead of the disease about the apiary are not likely to cause infection unless they serve to contaminate the water supply.

(18) *Nosema apis* suspended in water is destroyed by heating for 10 minutes at about 136° F. (58° C.).

(19) Suspended in honey, *Nosema apis* is destroyed by heating at about 138° F. (59° C.).

(20) *Nosema apis*, drying at room and outdoor temperatures, respectively, remained virulent for about 2 months, at incubator temperature about 3 weeks, and in a refrigerator about 7½ months.

(21) *Nosema apis* was destroyed in the presence of fermentative processes in a 20 per cent honey solution in 3 days at incubator temperature and in 9 days at outdoor temperature. In a 10 per cent sugar solution it was destroyed in from 7 to 11 days at room temperature.

(22) *Nosema apis* resisted putrefactive processes for 5 days at incubator temperature, for 2 weeks at room temperature, and for more than 3 weeks at outdoor temperature.

(23) *Nosema apis* when dry was destroyed in from 15 to 32 hours by direct exposure to the sun's rays.

(24) *Nosema apis* suspended in water was destroyed by exposure to the sun's rays in from 37 to 51 hours.

(25) *Nosema apis* if suspended in honey and exposed to the sun's rays frequently will be destroyed on account of the temperature of the honey which results from the exposure.

(26) *Nosema apis* remained virulent in honey for from 2 to 4 months at room temperature.

(27) *Nosema apis* in the bodies of dead bees ceased to be virulent in one week at incubator temperature, in 4 weeks at room temperature, in 6 weeks at outdoor temperature, and in 4 months in a refrigerator.

(28) *Nosema apis* in the bodies of dead bees lying on the soil ceased to be virulent in from 44 to 71 days.

(29) *Nosema apis* is readily destroyed by carbolic acid, a 1 per cent aqueous solution destroying it in less than 10 minutes.

(30) The time element which by the experiments is shown to be sufficient for the destruction of *Nosema apis* should be increased somewhat to insure their destruction in practical apiculture.

(31) The prognosis in Nosema-disease varies markedly from excellent, in case of strong colonies with a comparatively small percentage of Nosema-infected bees, to very grave, in case of weak ones with a high percentage of infected bees.

(32) From a technical point of view the results here given must be considered as being approximate only. They are, however, in most instances sufficient for practical purposes.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 781

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C. PROFESSIONAL PAPER May 31, 1919

DIGESTIBILITY OF SOME BY-PRODUCT OILS.[1]

By Arthur D. Holmes, *Specialist in Charge of Digestion Experiments, Office of Home Economics.*

CONTENTS.

INTRODUCTION.

In planning the experiments to determine the digestibility of edible fats it was early recognized that in order to be of greatest value the experiments with the different fats should be conducted under as nearly as possible identical conditions. Accordingly, the same experimental methods have been used throughout a series with 40 or more edible fats to which the present study is the most recent contribution. These methods were quite fully discussed in the initial report of this series.[2] As a result of this uniformity of method, the value reported for the digestibility of any individual fat discussed is directly comparable with the figures obtained for the others.

PREVIOUS INVESTIGATIONS.

Papers have appeared from time to time, reporting the digestibility of such animal fats [3] as lard; beef fat; mutton fat (kidney fat); butter; cream; chicken, goose, brisket, egg-yolk, and fish fats; goat's

[1] Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.
[2] U. S. Dept. Agr. Bul. 310 (1915).
[3] U. S. Dept. Agr. Buls. 310 (1915), 507 (1917).

Note.—This bulletin records studies of the digestibility of apricot-kernel oil, cherry-kernel oil, melon-seed oil, peach-kernel oil, pumpkin-seed oil, and tomato-seed oil. It is primarily of interest to students and investigators of food problems.

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butter; kid, hard-palate, and horse fats; oleo oil and oleo stearin; ox-marrow, ox-tail, and turtle fats. Other papers have reported the digestibility of a large number of vegetable fats,[1] including olive, cottonseed, peanut, coconut, and sesame oils; cocoa butter; and almond, black-walnut, Brazil-nut, butternut, English-walnut, hickory-nut, pecan, corn, soy-bean, sunflower-seed, Japanese mustard-seed, rapeseed, and charlock-seed oils. The oils of such nuts as almond, black and English walnuts, Brazil nuts, and pecan are ordinarily consumed as constituents of the nuts in which they naturally occur, but with these exceptions practically all of the oils studied are commonly separated from the materials in which they naturally occur before being used for table or culinary purposes.

POSSIBLE RECOVERY AND USE OF BY-PRODUCT OILS.

As a result of the enormously increased demand for fats and oils for both technical and edible purposes it has seemed desirable to make a study of the nature and value of fixed oils present in seeds and nuts not hitherto grown or utilized for the production of oil. For some time studies have been carried on by the Department of Agriculture to ascertain the commercial possibilities of recovering the fixed oils contained in many of the pits and seeds occurring as by-products of the fruit canning and drying industries. In 1908 Rabak [2] reported studies on the chemical and physical characteristics and the commercial uses and value of the fixed and volatile oils which may be obtained from the peach, apricot, and prune kernels. He estimates that from 210 to 420 tons of peach-kernel oil (fixed oil) and from 350 to 400 tons of apricot oil may be obtained from the by-product peach and apricot kernels produced in California alone. He also estimates that the amount of raisin-seed oil capable of being manufactured from waste raisin seed would be from 348 to 464 tons yearly.[3] He states [4] that the possible commercial utilization of the waste cherry pits of a normal year's output should yield 134 tons of fixed oil. In a recent paper the same author [5] states that the quantity of oil capable of being extracted from tomato seeds occurring as a by-product of tomatoes used for pulping purposes (catsups, etc.) would be about 343 tons annually.

From these findings it is apparent that the quantity of oil obtainable from the pits and seeds occurring as by-products is not small. In order to make the recovery of these oils a practical proposition even in those localities where the pits and seeds are to be had in suffi-

[1] U. S. Dept. Agr. Buls. 505 (1917), 630 (1918), 687 (1918).
[2] U. S. Dept. Agr. Bur. Plant Indus. Bul. 133 (1908), pp. 34.
[3] U. S. Dept. Agr. Bur. Plant Indus. Bul. 276 (1913), p. 30.
[4] U. S. Dept. Agr. Bul. 350 (1916), p. 16.
[5] U. S. Dept. Agr. Bul. 632 (1917), p. 9.

cient quantities to obviate long hauls it apparently was necessary to find some use for the entire pit.

The residue, commercially known as press cake, remaining after the expression of oil from peach, apricot, and cherry kernels, has much the same composition and nutritive value for stock feeding as the press cakes obtained from such oil seeds as soy bean, linseed, peanut, coconut, and cotton seed. Until very recently, however, the outer woody portion of the pits seemed to be of little value except for fuel purposes. Experimental tests and large-scale use of the carbon produced from the woody portion of fruit pits showed quite conclusively that this carbon is valuable, especially for the manufacture of gas masks. Thus, with a possible commercial demand existing for all portions of the fruit pits, it seemed desirable to give consideration to the utilization of these by-products.

While the oils obtainable from waste pits and seeds are satisfactory for a variety of technical purposes, it is of course evident that if they can be commercially prepared so that they are satisfactory for such purposes they should be available for food. Especially is this true at the present when a world-wide shortage of fats and oils exists. Accordingly, laboratory studies of the expression of oils from various kernels were made. The results of these studies showed that if care was observed both in the preparation of the pits and in the expression of oil from them a high-grade edible oil could be obtained.

If the peach, apricot, and cherry pits were allowed to stand for any length of time in the moist condition in which they were removed from the fruits, fermentation developed and the oil which was obtained was usually not suited for edible purposes. On the other hand, it was found in laboratory procedure that if the peach, apricot, and cherry kernels were dried, ground, and expressed by hydraulic pressure (i. e., "cold pressed"), the oils obtained were perfectly satisfactory for table purposes without any refining other than merely filtering. The peach, apricot, and cherry oils prepared in this laboratory by the above procedure were of a bland flavor, and when mixed with vinegar and condiments made excellent French dressing. In view of these findings it was decided to determine how well these oils are tolerated by the human body and to what extent they are digested. Accordingly, a supply of a number of oils which may be obtained from the by-products of the canning industry was secured, and the coefficients of digestibility were determined in the same manner as those of the other edible oils reported in previous publications.

DIGESTION EXPERIMENTS WITH MEN.

The subjects who assisted with this investigation were men in good health, whose ages ranged from 20 to 40 years. In order that the

squad should represent an average group of persons of these ages an attempt was made to secure individuals who should represent both the active and athletic type of person and the less active type employed at a sedentary occupation. The subjects were all students with sufficient understanding of nutrition and physiology to appreciate the necessity for strict adherence to the directions given them. At the same time they were not informed as to the specific purpose of the experiments in which they were participating.

In the case of the oils here discussed the quantities available for experimental purposes were insufficient to permit as large a number of tests as it has been the policy to make in such investigations. Accordingly, only four tests were made with apricot-kernel oil, four with cherry-kernel oil, three with melon-seed oil, three with peach-kernel oil, two with pumpkin-seed oil, and three with tomato-seed oil.

The test periods were of the customary three-day or nine-meal duration, and sufficient time elapsed between test periods so that the diets did not become too monotonous. During the periods which intervened between test periods the subjects secured their meals at their boarding places, and were thus afforded considerable variety in their diet. No record was made of body weight, but accurate weighings were made of the food served, the uneaten portion of food, and the feces resulting from the test diet. Both food and feces were analyzed to determine the percentages of protein, fat, and carbohydrate digested.

The individual oil under consideration was fed in a special cornstarch blancmange flavored with caramel and vanilla to mask the nature of the oil present. This blancmange was served in conjunction with a diet containing a minimum of fat and consisting of wheat biscuit, oranges, and sugar.

APRICOT-KERNEL OIL.

Apricot oil, like many other oils obtainable from the pits of fruits, has been used little if at all in this country for edibile purposes. A study reported by Rabak[1] of the commercial possibilities of apricot-kernel oil indicates that the chemical and physical properties of this oil are quite similar to those of the more widely used oils, such as cottonseed, peanut, coconut, corn, and soy-bean oils. Tests of the digestibility of apricot oil seemed especially desirable, as no information regarding it was found in literature.

The apricot oil studied in this investigation was obtained by cold pressing dried apricot kernels secured through the courtesy of M. E. Jaffa, of the University of California. The oil so obtained was of light-yellow color and free from any marked odor or taste. It pos-

[1] U. S. Dept. Agr. Bur. Plant Indus. Bul. 133 (1908), pp. 34.

sessed the essential characteristics of a salad oil and mixed with vinegar formed a very agreeable salad dressing. In order that the coefficient of digestibility obtained should be directly comparable with those for other fats in this series, the apricot oil here used was incorporated in a blancmange rather than used in the form of a salad dressing; but there is no reason to suppose that the difference in the manner of use would make any appreciable difference in the digestibility.

The following tables contain the essential data for interpreting the results of the digestion experiments with apricot oil:

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

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
Experiment No. 559, subject H. R. G.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing apricot oil	1,443.0	664.5	24.4	155.3	588.0	10.8
Wheat biscuit	369.0	33.2	39.1	5.5	285.3	5.9
Fruit	442.0	384.1	3.5	.9	51.3	2.2
Sugar	.....	.....	.....	.....	.....	.....
Total food consumed	2,254.0	1,081.8	67.0	161.7	924.6	18.9
Feces	82.0	.....	24.1	8.5	43.5	5.9
Amount utilized	.....	.....	42.9	153.2	881.1	13.0
Digestibility of entire ration (per cent)	.....	.....	64.0	94.7	95.3	68.8
Estimated digestibility of oil alone (per cent)	.....	.....	.....	99.7	.....	.....
Experiment No. 560, subject A. J. H.:						
Blancmange containing apricot oil	1,748.0	805.0	29.5	188.1	712.3	13.1
Wheat biscuit	18.0	1.6	1.9	.3	13.9	.3
Fruit	103.0	89.5	.8	.2	12.0	.5
Sugar	32.0	.....	.....	.....	32.0	.....
Total food consumed	1,901.0	896.1	32.2	188.6	770.2	13.9
Feces	79.0	.....	27.3	14.6	29.8	7.3
Amount utilized	.....	.....	4.9	174.0	740.4	6.6
Digestibility of entire ration (per cent)	.....	.....	15.2	92.3	96.1	47.5
Estimated digestibility of oil alone (per cent)	.....	.....	.....	96.4	.....	.....
Experiment No. 561, subject P. K.:						
Blancmange containing apricot oil	2,133.0	982.3	36.0	229.5	869.2	16.0
Wheat biscuit	371.0	33.4	39.3	5.6	286.8	5.9
Fruit	714.0	620.5	5.7	1.4	82.8	3.6
Sugar	111.0	.....	.....	.....	111.0	.....
Total food consumed	3,329.0	1,636.2	81.0	236.5	1,349.8	25.5
Feces	77.0	.....	26.3	10.9	33.6	6.2
Amount utilized	.....	.....	54.7	225.6	1,316.2	19.3
Digestibility of entire ration (per cent)	.....	.....	67.5	95.4	97.5	75.7
Estimated digestibility of oil alone (per cent)	.....	.....	.....	98.6	.....	.....
Experiment No. 562, subject C. J. W.:						
Blancmange containing apricot oil	2,224.0	1,024.1	37.6	239.3	906.3	16.7
Wheat biscuit	429.0	38.6	45.5	6.4	331.6	6.9
Fruit	937.0	814.2	7.5	1.9	108.7	4.7
Sugar	72.0	.....	.....	.....	72.0	.....
Total food consumed	3,662.0	1,876.9	90.6	247.6	1,418.6	28.3
Feces	95.0	.....	30.5	12.2	45.3	7.0
Amount utilized	.....	.....	60.1	235.4	1,373.3	21.3
Digestibility of entire ration (per cent)	.....	.....	66.3	95.1	96.8	75.3
Estimated digestibility of oil alone (per cent)	.....	.....	.....	98.8	.....	.....
Average food consumed per subject per day	928.8	457.6	22.6	69.5	371.9	7.2

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

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of apricot oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
559	H. R. G.	64.0	94.7	95.3	68.8	99.7
560	A. J. H.	15.2	92.3	96.1	47.5	96.4
561	P. K.	67.5	95.4	97.5	75.7	98.6
562	C. J. W.	66.3	95.1	96.8	75.3	98.8
Average		53.3	94.4	96.4	66.8	98.4

The coefficients of digestibility of the diet as a whole are comparable to those obtained in other tests with edible oils, being 53.3 per cent for protein, 94.4 per cent for fat, and 96.4 per cent for carbohydrate. On an average the subjects ate 23 grams of protein, 70 grams of fat, and 372 grams of carbohydrate daily, which had an energy value of 2,200 calories. The figure obtained for the digestibility of apricot oil alone, 98.4 per cent, indicates that this oil possesses a high nutritive value. In the tests referred to above, none of the subjects reported any unusual physiological conditions resulting from the ingestion of apricot oil. The results of these experiments as a whole, therefore, would seem to indicate that a high-grade cold-pressed apricot oil may be freely and safely used for edible purposes.

CHERRY-KERNEL OIL.

When cherry kernels are subjected to pressure and "cold pressed" a light-yellow, bland, fatty oil is obtained. Lewkowitsch[1] reports that in South Germany cold-pressed cherry-kernel oil is used for edible purposes. He further says that the oil expressed at higher temperature is used for soap making and illuminating purposes, but that cherry oil is not used as an adulterant of almond oil because of its tendency to become rancid.

In discussing the value and uses of cherry-kernel oil for other than edible purposes, Rabak[2] states that since this oil closely resembles almond, peach, and apricot oil it should be well adapted for use in pharmaceutical preparations.

The cherry-kernel oil studied in the experiments here reported was obtained by expression from dried cherry pits which were secured through the courtesy of a large canning establishment. The kernels were removed from the cherry pits by passing the pits through a mill having vertical grinding plates so set as to crack the pits without crushing the kernels. (The cracked pits were separated from the

[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan & Co. (Ltd.), 1909, vol. 2, p. 225.

[2] U. S. Dept. Agr. Bul. 350 (1916), pp. 8, 17.

kernels, without crushing them, by mechanical means and finally by hand picking.) The cleaned, thoroughly dried kernels were ground (using the fine knife) with an ordinary household meat chopper. The oil was expressed from the finely cut kernels by means of a laboratory press which developed a pressure of approximately 2,700 pounds per square inch and which was secured for the purpose from the Drug Plant and Poisonous Plant Laboratories of the Bureau of Plant Industry. The oil which was obtained in this manner was free from sediment, of a light-yellow color, and possessed a bland, fatty taste. When a sample mixed with vinegar and condiments was prepared as a French dressing, its origin could not be detected by those unaware of its source, though all agreed that the dressing was unusually appetizing.

The cherry-kernel oil was thoroughly mixed and incorporated in the usual cornstarch blancmange. The essential data resulting from the tests made with this oil are reported in the tables which follow:

Data of digestion experiments with cherry-kernel oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo-hydrate.	Ash.
Experiment No. 673, subject A. A. F.:						
Blancmange containing cherry-kernel oil	*Grams.* 1,681.0	*Grams.* 780.0	*Grams.* 59.8	*Grams.* 157.0	*Grams.* 669.2	*Grams.* 15.0
Wheat biscuit	345.0	31.0	36.6	5.2	266.7	5.5
Fruit	850.0	738.7	6.8	1.7	98.6	4.2
Sugar	179.0	.....	.....	.....	179.0	.....
Total food consumed	3,055.0	1,549.7	103.2	163.9	1,213.5	24.7
Feces	65.0	.....	18.0	10.6	27.6	8.8
Amount utilized	.....	.....	85.2	153.3	1,185.9	15.9
Digestibility of entire ration (per cent)	.....	.....	82.6	93.5	97.7	64.4
Estimated digestibility of oil alone (per cent)	.....	.....	.....	97.3	.....	.....
Experiment No. 674, subject P. K.:						
Blancmange containing cherry-kernel oil	2,366.0	1,097.8	84.2	221.0	941.9	21.1
Wheat biscuit	304.0	27.4	32.2	4.5	235.0	4.9
Fruit	403.0	350.2	3.2	.8	46.8	2.0
Sugar	148.0	.....	.....	.....	148.0	.....
Total food consumed	3,221.0	1,475.4	119.6	226.3	1,371.7	28.0
Feces	66.0	.....	20.5	10.2	30.0	5.3
Amount utilized	.....	.....	99.1	216.1	1,341.7	22.7
Digestibility of entire ration (per cent)	.....	.....	82.9	95.5	97.8	81.1
Estimated digestibility of oil alone (per cent)	.....	.....	.....	98.3	.....	.....
Experiment No. 675, subject J. C. M.:						
Blancmange containing cherry-kernel oil	2,149.0	997.2	76.5	200.7	855.5	19.1
Wheat biscuit	282.0	25.4	29.9	4.2	218.0	4.5
Fruit	635.0	551.8	5.1	1.3	73.6	3.2
Sugar	192.0	.....	.....	.....	192.0	.....
Total food consumed	3,258.0	1,574.4	111.5	206.8	1,339.1	26.8
Feces	76.0	.....	22.8	9.9	35.9	7.4
Amount utilized	.....	.....	88.7	196.3	1,303.2	19.4
Digestibility of entire ration (per cent)	.....	.....	79.6	95.2	97.3	72.4
Estimated digestibility of oil alone	.....	.....	.....	98.8	.....	.....

Data of digestion experiments with cherry-kernel oil in a simple mixed diet—Continued.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
Experiment No. 676, subject A. A. R.:						
Blancmange containing cherry-kernel oil	*Grams.* 1,166.0	*Grams.* 541.0	*Grams.* 41.5	*Grams.* 108.9	*Grams.* 464.2	*Grams.* 10.4
Wheat biscuit	178.0	16.0	18.9	2.7	137.6	2.8
Fruit	1,263.0	1,097.6	10.1	2.5	146.5	6.3
Sugar	131.0				131.0	
Total food consumed	2,738.0	1,654.6	70.5	114.1	879.3	19.5
Feces	53.0		18.1	7.9	21.2	5.8
Amount utilized			52.4	106.2	858.1	13.7
Digestibility of entire ration (per cent)			74.3	93.0	97.6	70.3
Estimated digestibility of oil alone (per cent)				97.4		
Average food consumed per subject per day	1,022.7	521.2	33.7	59.2	400.3	8.3

Summary of digestion experiments with cherry-kernel oil in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of cherry-kernel oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
673	A. A. F.	82.6	93.5	97.7	64.4	97.3
674	P. K.	82.9	95.5	97.8	81.1	98.3
675	J. C. M.	79.6	95.2	97.3	72.4	98.8
676	A. A. R.	74.3	93.0	97.6	70.3	97.4
Average		79.9	94.3	97.6	72.1	98.0

It will be noted from the above data that the diet as a whole was quite well digested, the values obtained being 79.9 per cent for protein, 94.3 per cent for fat, and 97.6 per cent for carbohydrate. On an average the subjects ate 34 grams of protein, 59 grams of fat, and 400 grams of carbohydrate, which supplied 2,270 calories of energy. No attempt was made to ascertain how much cherry-kernel oil could be eaten daily without producing a laxative effect; but, since one of the subjects ate aproximately 74 grams daily for the three-day period, it seems apparent that the limit of tolerance for this oil is in excess of this amount.

The high digestibility of cherry-kernel oil, 98 per cent, when considered in connection with the pleasing appearance and flavor of the cold-pressed oil, warrants the belief that when cherry pits are obtainable in quantity they should prove a valuable source of a high-grade culinary or table oil.

MELON-SEED OIL.

While melon (cantaloup) seeds are not available in this country in sufficient quantities to be of commercial importance as a source of

oil, Lewkowitsch reports[1] that melon seeds form an article of commerce on the Slave Coast and Gold Coast of West Africa. In studies of the relative commercial value of unutilized oil-producing seeds and nuts as possible sources of oil, H. S. Bailey, oil specialist of the Bureau of Chemistry, gave some attention to this oil. A sample of cantaloup-seed oil was expressed from cleaned, dried cantaloup seed in a continuous-process-expeller type of oil press under conditions approximating those of the commercial oil mill. The cold-pressed oil which was obtained was of a light-yellow color without characteristic odor or flavor. Since this oil seemed to possess the desirable characteristics of a table oil, it was decided to determine its digestibility, and accordingly three tests were made, the results of which are reported in the following table:

Data of digestion experiments with cantaloup-seed oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
Experiment No. 891, subject G. S. M.:						
Blancmange containing cantaloup-seed oil	*Grams.* 1,057.0	*Grams.* 495.8	*Grams.* 18.6	*Grams.* 124.4	*Grams.* 409.8	*Grams.* 8.4
Wheat biscuit	120.0	10.8	12.7	1.8	92.8	1.9
Fruit	1,153.0	1,002.0	9.2	2.3	133.7	5.8
Sugar	293.0	.....	.....	.....	293.0	.....
Total food consumed	2,623.0	1,508.6	40.5	128.5	929.3	16.1
Feces	39.0	.....	10.3	2.9	23.5	2.3
Amount utilized	.....	.....	30.2	125.6	905.8	13.8
Digestibility of entire ration (per cent)	.....	.....	74.6	97.7	97.5	85.7
Estimated digestibility of oil alone (per cent)	.....	.....	.....	100.0	.....	.....
Experiment No. 892, subject M. L. M.:						
Blancmange containing cantaloup-seed oil	862.0	404.4	15.2	101.4	334.2	6.8
Wheat biscuit	231.0	20.8	24.5	3.5	178.5	3.7
Fruit	932.0	809.9	7.5	1.9	108.1	4.6
Sugar	150.0	.....	.....	.....	150.0	.....
Total food consumed	2,175.0	1,235.1	47.2	106.8	770.8	15.1
Feces	37.0	.....	11.6	5.9	15.2	4.3
Amount utilized	.....	.....	35.6	100.9	755.6	10.8
Digestibility of entire ration (per cent)	.....	.....	75.4	94.5	98.0	71.5
Estimated digestibility of oil alone (per cent)	.....	.....	.....	97.8	.....	.....
Experiment No. 893, subject W. O'C.:						
Blancmange containing cantaloup-seed oil	1,092.0	512.3	19.2	128.5	423.4	8.6
Wheat biscuit	179.0	16.1	19.0	2.7	138.4	2.8
Fruit	1,221.0	1,061.1	9.8	2.4	141.6	6.1
Sugar	528.0	.....	.....	.....	528.0	.....
Total food consumed	3,020.0	1,589.5	48.0	133.6	1,231.4	17.5
Feces	63.0	.....	16.1	10.5	30.6	5.8
Amount utilized	.....	.....	31.9	123.1	1,200.8	11.7
Digestibility of entire ration (per cent)	.....	.....	66.5	92.1	97.5	66.9
Estimated digestibility of oil alone (per cent)	.....	.....	.....	96.7	.....	.....
Average food consumed per subject per day	868.7	481.5	15.1	41.0	325.7	5.4

[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan & Co. (Ltd.), 1909, vol. 2, p. 127.

Summary of digestion experiments with cantaloup-seed oil in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of cantaloup-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
891	G. S. M.	74.6	97.7	97.5	85.7	100.0
892	M. L. M.	75.4	94.5	98.0	71.5	97.8
893	W. O'C.	66.5	92.1	97.5	66.9	96.7
Average		72.2	94.8	97.7	74.7	98.2

The value 98.2 per cent obtained for the digestibility of the cantaloup-seed oil alone indicates that this oil is very completely digested. An average of 15 grams of protein, 41 grams of fat, and 326 grams of carbohydrate, which supplied 1,730 calories, was eaten per man daily, of which 72 per cent of the protein, 95 per cent of the fat, and 98 per cent of the carbohydrate was digested, showing that the cantaloup-seed oil did not exert any unfavorable influence on the digestibility of the diet as a whole. The cantaloup-seed-oil blancmange was as palatable as the similar dishes prepared with other oils. It should be noted, however, that because of the limited amount of cantaloup-seed oil available for experimental purposes, the actual amount of blancmange eaten daily by the subjects was considerably less than in most of the experiments reported in this investigation.

The experiments here reported may, nevertheless, be considered as evidence that good quality cold-pressed cantaloup-seed oil is very satisfactory for edible purposes.

PEACH-KERNEL OIL.

The peach-kernel oil which was studied in the experiments reported below was expressed under laboratory conditions. A liberal supply of peach stones was obtained from a large eastern fruit-canning establishment. The peach stones were shipped as soon as removed from the fruit, in the moist condition, and when they arrived at the laboratory they had commenced to ferment. The stones were immediately cracked by hand and the kernels carefully separated. These were slowly but thoroughly dried, after which they were finely ground with an ordinary meat chopper. The ground kernels were subjected to hydraulic pressure and an oil of a clear pale-yellow color with an agreeable nutlike taste, resembling in physical appearance highly refined cottonseed oil, was obtained. The oil was practically free from sediment and received no treatment, other than filtering, before it was used.

Since the amount of peach-kernel oil available for experimental purposes was limited, only three tests with this oil were completed. The results which were obtained in these tests are included in the tables below:

Data of digestion experiments with peach-kernel oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrates.	Ash.
Experiment No. 724, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing peach-kernel oil.	1,751.0	757.0	67.6	219.4	693.9	13.1
Wheat biscuit	278.0	25.0	29.5	4.2	214.9	4.4
Fruit	500.0	434.5	4.0	1.0	58.0	2.5
Sugar	172.0	.....	.....	.....	172.0	.....
Total food consumed	2,701.0	1,216.5	101.1	224.6	1,138.8	20.0
Feces	82.0	.....	8.6	17.9	48.6	6.9
Amount utilized	.....	.....	92.5	206.7	1,090.2	13.1
Digestibility of entire ration (per cent)	.....	.....	91.5	92.0	95.7	65.5
Estimated digestibility of oil alone (per cent)	.....	.....	.....	95.5	.....	.....
Experiment No. 725, subject J. C. M.:						
Blancmange containing peach-kernel oil.	1,743.0	753.5	67.3	218.4	690.7	13.1
Wheat biscuit	431.0	38.8	45.7	6.4	333.2	6.9
Fruit	1,177.0	1,022.8	9.4	2.4	136.5	5.9
Sugar	140.0	.....	.....	.....	140.0	.....
Total food consumed	3,491.0	1,815.1	122.4	227.2	1,300.4	25.9
Feces	89.0	.....	7.8	8.0	65.8	7.4
Amount utilized	.....	.....	114.6	219.2	1,234.6	18.5
Digestibility of entire ration (per cent)	.....	.....	93.6	96.5	94.9	71.4
Estimated digestibility of oil alone (per cent)	.....	.....	.....	100.0	.....	.....
Experiment No. 726, subject A. A. R.:						
Blancmange containing peach-kernel oil.	800.0	345.9	30.9	100.2	317.0	6.0
Wheat biscuit	391.0	35.2	41.4	5.9	302.2	6.3
Fruit	1,253.0	1,088.9	10.0	2.5	145.3	6.3
Sugar	175.0	.....	.....	.....	175.0	.....
Total food consumed	2,619.0	1,470.0	82.3	108.6	939.5	18.6
Feces	85.0	.....	28.0	14.1	33.5	9.4
Amount utilized	.....	.....	54.3	94.5	906.0	9.2
Digestibility of entire ration (per cent)	.....	.....	66.0	87.0	96.4	49.5
Estimated digestibility of oil alone (per cent)	.....	.....	.....	94.3	.....	.....
Average food consumed per subject per day.	979.0	500.2	34.0	62.3	375.4	7.2

Summary of digestion experiments with peach-kernel oil in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of peach-kernel oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
724	P. K.	91.5	92.0	95.7	65.5	95.5
725	J. C. M.	93.6	96.5	94.9	71.4	100.0
726	A. A. R.	66.0	87.0	96.4	49.5	94.3
Average		83.7	91.8	95.7	62.1	96.6

The results of three tests with peach-kernel oil show that the diet as a whole was well assimilated, the digestibility of the different constituents being 83.7 per cent for protein, 91.8 per cent for fat, and 95.7 per cent for carbohydrate. An average of 34 grams of protein, 62 grams of fat, and 375 grams of carbohydrate, which supplied 2,200 calories, was eaten per man daily. The subjects all reported that they felt in normal physical condition throughout the test period, which indicated that peach-kernel oil when included as a part of a simple mixed diet was well tolerated. The digestibility of peach-kernel oil alone, 96.6 per cent, may be considered as evidence that this oil is very well assimilated and would prove a valuable food oil.

PUMPKIN-SEED OIL.

The oil that is obtained by cold expression of pumpkin seeds is classified as a semidrying oil and is of a slightly greenish-yellow color. In South Russia this oil is prepared on a commercial scale by roasting the pumpkin seeds, after which the oil is hot pressed. Lewkowitsch [1] states that the hot-pressed oil is viscous, of a brownish-green color by transmitted light, and of a deep red color by reflected light. He further states that attempts to bleach and refine hot-pressed pumpkin-seed oil have not met with success.

While the amount of pumpkin canned at present is not large, both the output of the individual factories and the number of canneries packing pumpkin are increasing and the indications are that eventually the available supply of pumpkin seed will be sufficient to warrant commercial consideration.

The pumpkin-seed oil studied in the tests here reported was obtained through the courtesy of H. S. Bailey, of the Bureau of Chemistry. It was prepared by cold pressing a supply of pumpkin seeds obtained from a commercial canning establishment. It may be assumed that this oil was very nearly representative of high-grade pumpkin-seed oil of commerce. Since only a very limited supply of pumpkin-seed oil was available, only two tests were possible. The results which were obtained in these tests are reported in the tables following:

[1] Chemical Technology and Analysis of Oils, Fats, and Waxes. London: Macmillan & Co. (Ltd.), 1909, vol. 2, p. 124.

Data of digestion experiments with pumpkin-seed oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
Experiment No. 829, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing pumpkin-seed oil	1,429.0	723.2	25.1	216.4	456.4	7.9
Wheat biscuit	368.0	33.1	39.0	5.5	284.5	5.9
Fruit	318.0	276.3	2.6	.6	36.9	1.6
Sugar	236.0	.....	.....	.....	236.0	.....
Total food consumed	2,351.0	1,032.6	66.7	222.5	1,013.8	15.4
Feces	61.0	.....	18.2	11.1	26.6	5.1
Amount utilized	.....	.....	48.5	211.4	987.2	10.3
Digestibility of entire ration (per cent)	.....	.....	72.7	95.0	97.4	66.8
Estimated digestibility of oil alone (per cent)	.....	.....	.....	97.6	.....	.....
Experiment No. 830, subject G. S. M.:						
Blancmange containing pumpkin-seed oil	1,524.0	771.3	26.8	230.7	486.8	8.4
Wheat biscuit	231.0	20.8	24.5	3.5	178.5	3.7
Fruit	632.0	549.2	5.0	1.3	73.3	3.2
Sugar	445.0	.....	.....	.....	445.0	.....
Total food consumed	2,832.0	1,341.3	56.3	235.5	1,183.6	15.3
Feces	91.0	.....	26.6	11.9	43.2	9.3
Amount utilized	.....	.....	29.7	223.6	1,140.4	6.0
Digestibility of entire ration (per cent)	.....	.....	52.8	94.9	96.4	39.2
Estimated digestibility of oil alone (per cent)	.....	.....	.....	98.7	.....	.....
Average food consumed per subject per day	863.8	395.7	20.5	76.5	366.2	5.1

Summary of digestion experiments with pumpkin-seed oil in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of pumpkin-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
829	P. K.	72.7	95.0	97.4	66.8	97.6
830	G. S. M.	52.8	94.9	96.4	39.2	98.7
Average		62.8	95.0	96.9	53.0	98.2

In the two tests reported above the subjects ate 21 grams of protein, 77 grams of fat, and 366 grams of carbohydrate, which supplied 2,235 calories of energy. Of the 76 grams of fat eaten daily 74.5 grams was pumpkin-seed oil. As they reported no laxative effects resulting from this diet it may be concluded that the limit of tolerance for pumpkin-seed oil is in excess of 75 grams daily. The diet as a whole was well assimilated, for the digestibility was found to be 62.8 per cent for protein, 95 per cent for fat, and 96.9 per cent for carbohydrate. The value 98.2 per cent for the digestibility of pumpkin-seed oil implies that this oil is well assimilated. While the supply of pumpkin-seed oil available was sufficient for only two tests, the results of these seem to justify the conclusion that pumpkin-seed oil of good quality would be a valuable food and possess a dietary value similar to that of better-known edible oils.

TOMATO-SEED OIL.

While definite figures regarding the amount of tomato seed resulting from the commercial manufacture of tomato pulp and catsup are not available, it has been estimated by Rabak[1] that approximately 1,500 tons of dry tomato seeds could be obtained annually. Dried tomato seeds contain approximately the same proportion of fixed oil as such well-known oil seeds as cotton seed, soy beans, etc. Tomato-seed oil may be obtained by either extracting or pressing the tomato seeds. When the seeds are subjected to the action of such solvents as ether or carbon tetrachlorid, a pale greenish-yellow oil is extracted. Expressed tomato-seed oil is of higher quality and usually requires less refining, but a smaller yield is obtained.

From a study of the physical and chemical characteristics of tomato-seed oil as compared with those of cottonseed, soy bean, sesame, and corn oils, it appeared to Rabak[1] that tomato-seed oil should be equally useful and applicable to the same purposes as better-known oils of commerce. Accordingly, digestion experiments were here conducted to determine the digestibility of a well-refined tomato-seed oil prepared in the Bureau of Plant Industry laboratories.

This oil, which was of a brownish-yellow color, possessed a slight but quite distinctive odor and flavor. Both the odor and flavor were very completely masked when the oil was incorporated in the usual cornstarch blancmange.

The results which were obtained in the three tests that were made of tomato-seed oil are recorded in the tables which follow:

Data of digestion experiments with tomato-seed oil in a simple mixed diet.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
Experiment No. 608, subject P. K.:	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Blancmange containing tomato-seed oil	2,142.0	1,110.4	38.8	194.7	704.3	93.8
Wheat biscuit	359.0	32.3	38.1	5.4	277.5	5.7
Fruit	692.0	601.3	5.5	1.4	80.3	3.5
Sugar	143.0	.....	.....	.....	143.0	.....
Total food consumed	3,336.0	1,744.0	82.4	201.5	1,205.1	103.0
Feces	79.0	.....	26.1	20.9	23.3	8.7
Amount utilized	.....	.....	56.3	180.6	1,181.8	94.3
Digestibility of entire ration (per cent)	.....	.....	68.3	88.1	98.1	91.6
Estimated digestibility of oil alone (per cent)	.....	.....	.....	93.3	.....	.....
Experiment No. 609, subject J. C. M.:						
Blancmange containing tomato-seed oil	1,505.0	780.2	27.2	136.8	494.9	65.9
Wheat biscuit	306.0	27.5	32.4	4.6	236.5	5.0
Fruit	1,030.0	895.1	8.2	2.1	119.5	5.1
Sugar	103.0	.....	.....	.....	103.0	.....
Total food consumed	2,944.0	1,702.8	67.8	143.5	953.9	76.0
Feces	91.0	.....	28.9	12.4	41.0	8.7
Amount utilized	.....	.....	38.9	131.1	912.9	67.3

[1] U. S. Dept. Agr. Bul. 632 (1917), pp. 15.

Data of digestion experiments with tomato-seed oil in a simple mixed diet—Con.

Experiment, subject, and diet.	Weight of food.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbohydrate.	Ash.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Grams.*
Experiment No. 609, subject J. C. M.—Con.						
Digestibility of entire ration (per cent)	.....	.....	57.4	91.4	95.7	88.6
Estimated digestibility of oil alone (per cent)	.....	.....	.....	97.5	.....	.....
Experiment No. 610, subject C. J. W.:						
Blancmange containing tomato-seed oil	1,960.0	1,016.1	35.5	178.2	644.4	85.8
Wheat biscuit	469.0	42.2	49.7	7.0	362.6	7.5
Fruit	746.0	648.3	6.0	1.5	86.5	3.7
Sugar	45.0	.....	.....	.....	45.0	.....
Total food consumed	3,220.0	1,706.6	91.2	186.7	1,138.5	97.0
Feces	103.0	.....	32.1	16.3	45.8	8.8
Amount utilized	.....	.....	59.1	170.4	1,092.7	88.2
Digestibility of entire ration (per cent)	.....	.....	64.8	91.3	96.0	90.9
Estimated digestibility of oil alone (per cent)	.....	.....	.....	96.6	.....	.....
Average food consumed per subject per day	1,055.6	572.6	26.8	59.1	366.4	30.7

Summary of digestion experiments with tomato-seed oil in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of tomato-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
608	P. K.	68.3	88.1	98.1	91.6	93.3
609	J. C. M.	57.4	91.4	95.7	88.6	97.5
610	C. J. W.	64.8	91.3	96.0	90.9	96.6
Average		63.5	90.3	96.6	90.4	95.8

In the tests with tomato-seed oil the digestibility of the diet as a whole was found to be 63.5 per cent for protein, 90.3 per cent for fat, and 96.6 per cent for carbohydrate. On an average, the subjects ate 27 grams of protein, 59 grams of fat, and 366 grams of carbohydrate, the energy value of which was 2,100 calories. The subjects ate approximately 57 grams of tomato-seed oil daily. In one instance, Experiment No. 608, subject P. K., an average of over 67 grams of fat or approximately 65 grams of tomato-seed oil was eaten daily. In all of the tests the subjects reported that they were in normal physical condition and so it may be assumed that tomato-seed oil is fairly well tolerated by the human body.

DISCUSSION.

The table beyond summarizes the results of the digestion experiments with oils expressed from apricot, cherry, and peach kernels, and from melon, pumpkin and tomato seeds. The figures reported

for the digestibility of the protein, fat, and carbohydrate of the entire ration and those reported for the digestibility of the oil alone are obtained by averaging the results of the individual tests with the different oils.

Summary of digestion experiments with by-products oils.

Kind of oil.	Number of experiments.	Digestibility of entire ration.			Average amount of oil eaten per man per day.	Digestibility of oil alone.
		Protein.	Fat.	Carbohydrate.		
		Per cent.	*Per cent.*	*Per cent.*	*Grams.*	*Per cent.*
Apricot-kernel oil	4	53.3	94.4	96.4	68	98.4
Cherry-kernel oil	4	79.9	94.3	97.6	57	98.0
Melon-seed oil	3	72.2	94.8	97.7	40	98.2
Peach-kernel oil	3	83.7	91.8	95.6	60	96.6
Pumpkin-seed oil	2	62.8	95.0	96.9	75	98.2
Tomato-seed oil	3	63.5	90.3	96.6	57	95.8

The amount of oil consumed in the above experiments was not as large as in the early experiments of this series, but, as noted on page 4, this was due to an inadequate supply of the oils under consideration and not to the quality of the oil. The small supply of oils also limited the number of experiments which could be made.

No attempt was made to determine the upper limit of tolerance of these oils, but since in these tests as much as approximately 80 grams of apricot-kernel oil, 74 grams of cherry-kernel oil, 43 grams of melon (cantaloup) seed oil, 73 grams of peach-kernel oil, 77 grams of pumpkin-seed oil, and 65 grams of tomato-seed oil was eaten by one of the subjects for three successive days without physiological disturbances being noted, it is safe to conclude that the limit of tolerance is in excess of these amounts.

The coefficients of digestibility of the by-products oils, 98.4 per cent for apricot-kernel oil, 98 per cent for cherry-kernel oil, 98.2 per cent for melon (cantaloup) seed oil, 96.6 per cent for peach-kernel oil, 98.2 per cent for pumpkin-seed oil, and 95.8 per cent for tomato-seed oil indicates that these oils are very well assimilated by the body and possess a nutritive value equal to that of other better known edible oils, such as cottonseed, corn, peanut, coconut, soybean, and olive oils. In general the experiments here reported indicate that as far as tolerance and assimilation are concerned apricot, cherry, and peach kernel, and melon (cantaloup), pumpkin, and tomato-seed oils, which at present are practically unutilized, are wholesome, nutritious foods, and should prove satisfactory for edible purposes.

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A STUDY OF THE ALKALI-FORMING BACTERIA FOUND IN MILK.

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CONTENTS.

HISTORICAL REVIEW.

Occasionally references to the alkali-forming bacteria are found in bacteriological literature. This group of bacteria has not received much attention, probably because under the ordinary conditions of plating their presence can not be detected, and as a consequence their rather wide distribution has been overlooked.

The fact that alkali-forming bacteria are often present in market milk in large numbers was first brought to the attention of the authors during some studies (1) [1] on the bacteriology of raw and pasteurized milk. At that time no suitable means were available for obtaining any exact figures on their numbers in market milk, so they were classed with the inert types of bacteria. Wolff (12) in a study of bacteria which developed in milk found nonliquefying short rods, colonies of which resembled those of the colon-aerogenes group. These organisms were strict aerobes which produced neither acid nor gas but turned milk alkaline without any other change. Shippen (10) also found organisms, in the milk supply of Baltimore, which gave an alkaline reaction in milk without peptonizing or coagulating it. He found that these organisms in cultural reactions closely resembled

[1] The numbers in parentheses refer to "Literature cited" at end of bulletin.

Bacillus fæcalis alkaligenes of Petruschky, also *Bacillus No. 66* described by Conn (4). *B. fæcalis alkaligenes* described by Petruschky (8) is well known as an organism which turns milk distinctly alkaline without producing any other apparent change. This is the characteristic reaction of the alkali-forming group of bacteria which separates them distinctly from other organisms which turn milk alkaline and cause peptonization at the same time.

Seiffert and Wymer (9) in 1912 reported alkali formation in litmus medium caused by bacteria which used proteins only to the smallest extent for this reaction, the chief source being citric acid and lactic acid produced by cleavage from the lactose. Both of these acids were decomposed to the alkali carbonates or bicarbonates.

Unfortunately it has been and still is the custom of most bacteriologists to consider all organisms which produce an alkaline reaction in milk as alkali-forming bacteria. It is generally assumed that the alkaline change is due to the formation of ammonia which is formed from the decomposition of the protein. Consequently when the alkali-forming bacteria are mentioned, the ammonia-producing, peptonizing types are usually brought to one's mind. Since the alkali-forming bacteria as they are considered in this paper include only those bacteria which produce an alkaline reaction due to the formation of carbonates or bicarbonates, it is necessary to define the limits of this group.

DEFINITION OF THE ALKALI-FORMING GROUP OF BACTERIA.

The alkali-forming bacteria are characterized by ability to produce an alkaline reaction in milk without visible signs of peptonization. This reaction is due to the oxidation of the salts of the organic acids present in milk to alkaline carbonates. In litmus milk the alkaline change is usually noticeable within 5 days when incubation is at 30° C. Often the change may be seen in 48 hours and occasionally a period of incubation longer than 5 days is necessary before it appears.

CAUSE OF THE ALKALINE REACTION IN MILK.

The alkaline production in milk during a period of 7 days' incubation at 30° C. is believed to be due almost entirely to formation of alkaline carbonates from the oxidation of the salts of organic acids, presumably citric acid, since fresh milk was used. This belief is based on the following facts: First, it was found that a number of the cultures tested used up all the citric acid in milk within a period of 7 days when incubated at 30° C., during which period the milk changed to reaction toward the alkaline side; and second, only a few cultures produced any ammonia in milk during a period of 7 days'

incubation at 30° C. and even then there was not a sufficient amount formed to affect the titration appreciably.

That citric acid was used up as the reaction became alkaline is shown by the results in Table 1. Since culture No. 12 was the only one which could produce even a trace of ammonia during incubation for 7 days at 30° C., it is assumed that the alkaline change of about 16 cubic centimeters tenth-normal alkali was due to the production of carbonates resulting from the oxidation of the citric acid. It may be observed, however, that in order to account for the alkaline change it would be necessary to oxidize to carbonates about one-half of the citric acid actually found to have been used up. Since the quantity of citric acid fermented, if calculated as carbonate, would be about twice as much as is necessary to account for the reduction in acidity of the milk, it seems evident that about one-half of the citric acid is oxidized to carbonates while the remainder is probably converted into other organic acids and is not carried so far as the alkaline carbonates.

TABLE 1.—*Alkaline change in milk due to oxidation of the citric acid.*

Culture No.	Titration (N/10 NaOH per 100 c. c. of milk).		Alkaline change (c. c. of N/10 alkali per 100 c. c. of milk.	Citric acid in 100 c. c. of milk.		Citric acid necessary to produce enough carbonate to account for alkaline change in milk.	Citric acid fermented but not oxidized to carbonates.
	Control.	After 7 days' incubation.		Control.	After 7 days' incubation.		
	C. c.	*C. c.*	*C. c.*	*Gram.*	*Gram.*	*Gram.*	*Gram.*
12	19.20	2.70	16.5	0.2013	0.0	0.1056	0.0957
60	19.20	3.20	16.0	.2013	0.0	.1024	.0989
130	19.20	2.60	16.6	.2013	0.0	.1063	.0950

The citric acid was determined according to the modification of Beau's (3) method. Denige's reagent was used but changed slightly as follows: To 50 grams of red oxid of mercury in 500 cubic centimeters distilled water add 110 cubic centimeters of concentrated sulphuric acid little by little and shake well until the solution is complete; dilute to 1 liter, heat to boiling, and filter when cold. The method of analysis was as follows: Place 50 cubic centimeters of milk in a 200 cubic centimeter graduated flask, add 75 cubic centimeters distilled water and 50 cubic centimeters of reagent, agitate gently, fill to mark, and mix well. Allow to settle and filter through a dry Swedish filter 12.5 centimeters No. 0 until only a faint opalescence remains. Then oxidize 100 cubic centimeters of the filtrate which corresponds to 25 cubic centimeters of milk at 75° C. by adding 1 per cent solution of potassium permanganate drop by drop until the precipitate acquires a light-brown color and settles rapidly. About

4.5 cubic centimeters of permanganate solution is sufficient. After boiling from 1 to 2 minutes the precipitate becomes almost white. If the precipitate remains colored, add from 2 to 3 drops of hydrogen peroxid solution and shake well 1 or 2 minutes. When cold, filter by weak suction in a Gooch crucible, wash with distilled water, once with alcohol, dry at 100° C., and weigh. The weight of the precipitate multiplied by 0.271 equals anhydrous citric acid. The method is accurate in milk, as shown by the fact that triplicate determinations upon a sample of milk gave the following results: No. 1, 0.2246 gram, No. 2, 0.2270 gram, and No. 3, 0.2285 gram of citric acid to 100 cubic centimeters of milk. The amount of citric acid found in the three analyses differs only by 4 milligrams.

That ammonia played little or no part in causing the alkaline reaction, especially during the first 7 days of the incubation, is shown in Table 2. Experiments were carried on to determine the amount of ammonia produced after periods of 7, 14, and 30 days of incubation at 30° C. Three sets of tubes of skim milk were inoculated with cultures of the alkali-forming bacteria and the ammonia was determined together with the reaction of the milk in each of the sets after the various periods of incubation. Each tube of milk contained 10 cubic centimeters and was marked so as to show the total volume. The amount of water lost by evaporation was made up at the time of the determination of ammonia and acidity. Five cubic centimeters or one-half of the 10 cubic centimeters was then removed for the ammonia test and the remaining 5 cubic centimeters portion was then titrated in order to determine the reaction. The ammonia was determined by the Folin method (6) with 0.2 cubic centimeter of oxyl alcohol added to prevent foaming. When the quantity of ammonia and the change in reaction of the milk was known, it was possible to calculate the amount of change in reaction due to the ammonia formed, and the difference between that and the total change was assumed to be due to formation of sodium carbonate or bicarbonate.

As may be seen from the results in Table 2, the reduction of the acidity in 58 of the 68 cultures during the first 7 days' incubation was due entirely to the formation of alkaline carbonates. In 10 cultures there was slight amount of ammonia produced, which as the results show accounted for only a very small part of the alkali produced. Generally speaking, the small amount of ammonia produced by the alkali-forming bacteria shows that the reduction of acidity in milk after 7 days at 30° C. was due almost entirely to carbonates or bicarbonates.

TABLE 2.—*Alkali production in skim milk incubated at 30° C.*

Culture No.	7 days.						14 days.						30 days.					
	C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.			C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.			C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.		
				Change from control.	Due to NH_3.	Due to Na_2CO_3 or $NaHCO_3$.				Change from control.	Due to NH_3.	Due to Na_2CO_3 or $NaHCO_3$.				Change from control.	Due to NH_3.	Due to Na_2CO_3 or $NaHCO_3$.
	C. c.	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*
Control	0.50	4.26	+22.00	.....	.....	.....	0.50	4.26	+22.00	.....	.....	.....	0.52	4.43	+22.00	.....	.....	.....
10	0.68	5.79	+ 2.00	20.00	0.90	19.10	1.40	11.92	+ 6.80	15.20	4.51	10.69	2.48	21.12	+17.00	5.00	9.82	(2)
12	.53	4.51	+ 2.80	19.20	.15	19.05	1.33	11.33	+ 7.40	14.60	4.16	10.44	2.49	21.20	+15.40	6.60	9.86	(2)
31	.32	2.72	+ .20	21.80	(1)	21.80	.46	3.92	+ .40	21.60	(1)	21.60	.54	4.60	+ 1.00	21.00	.10	20.90
49	.69	5.87	+ 4.60	17.40	.95	16.45	1.40	11.92	+ 7.00	15.00	4.51	10.49	2.49	21.20	+12.80	9.26	9.86	(2)
59	.30	2.55	+ 1.00	21.00	(1)	21.00	.58	4.94	+ 1.40	20.60	.40	20.20	.87	7.41	+ 2.20	19.80	1.75	18.05
60	.42	3.58	+ 2.60	19.40	(1)	13.40	1.17	9.96	+ 2.80	19.20	3.35	15.85	1.20	10.22	+ 3.80	18.20	3.41	14.79
61	.32	2.72	+ 2.00	20.00	(1)	20.00	.58	4.94	+ 1.40	20.60	.40	20.20	.70	5.96	+ 2.40	19.60	.90	18.70
62	.15	1.28	+16.80	5.20	.....	5.20	.36	3.06	+ 1.40	20.60	(1)	20.60	.93	7.92	+ 3.20	18.80	2.05	16.75
66	.14	1.19	+17.00	5.00	.....	5.00	.23	1.96	+ 3.00	19.00	(1)	19.00	.85	7.24	+ 3.20	18.80	1.65	17.15
72	.26	2.21	+ 3.40	18.60	.....	18.60	.31	2.65	+ 3.00	19.00	(1)	19.00	.53	4.51	+ 1.00	21.00	.05	20.95
73	.22	1.87	+ 2.60	19.40	.....	19.40	.10	.85	+ 1.40	20.60	(1)	20.60	.44	3.75	+ 1.60	20.40	(1)	20.40
101	.18	1.53	+ 7.40	14.60	.....	14.60	.16	1.36	+ 1.60	20.40	(1)	20.40	.57	4.85	+ 2.60	19.40	.25	19.15
102	.11	.94	+ 7.80	14.20	.....	14.20	.18	1.53	+ 1.40	20.60	(1)	20.60	.80	6.81	+ 2.40	19.60	1.40	18.20
103	.51	4.34	+ 3.00	19.00	.05	18.95	.26	2.21	+ 1.00	21.00	(1)	21.00	.30	2.55	+ 1.00	21.00	(1)	21.00
104	.12	1.02	+ 6.40	15.60	(1)	15.60	.13	1.11	+ 1.80	20.20	(1)	20.20	.44	3.75	+ 2.20	19.80	(1)	19.80
105	(1)	(1)	+10.60	11.40	.....	11.40	.16	1.36	+ 2.80	19.20	(1)	19.20	.47	4.00	+ 2.00	20.00	(1)	20.00
106	.18	1.53	+ 3.80	18.20	.....	18.20	.55	4.68	+ 2.60	19.40	.25	19.15	.80	6.81	+ 2.00	20.00	1.40	18.60
107	.06	.51	+10.20	11.80	.....	11.80	.47	4.00	+21.00	1.00	(1)	1.00	.77	6.56	+45.20	.....	1.25	(2)
108	.13	1.11	+ 1.00	21.00	.....	21.00	.15	1.28	+ 1.60	20.40	(1)	20.40	.51	4.34	+ 1.60	20.40	(1)	20.40
111	.11	.94	+ 9.40	12.60	.....	12.60	.35	2.98	+ 1.60	20.40	(1)	20.40	.76	6.47	+ 2.20	19.80	1.20	18.60
112	.37	3.15	+ 5.60	16.40	.....	16.40	.99	8.43	+ 6.60	15.40	2.45	12.95	2.39	20.35	+10.20	11.80	9.36	2.44
113	.50	4.26	+ 3.00	19.00	.....	19.00	1.15	9.79	+ 7.80	14.20	3.25	10.95	2.08	17.71	+15.80	6.20	7.81	(2)
114	.07	.60	+ 2.20	19.80	(1)	19.80	.06	.51	+ 2.80	19.20	(1)	19.20	.24	2.04	+ 2.40	19.80	(1)	19.60
116	.36	3.15	+ 1.40	20.60	(1)	20.60	.60	5.11	+ 4.00	18.00	.50	17.50	1.20	10.22	+ 4.20	17.80	3.41	14.39
117	.07	.60	+ 5.60	16.40	(1)	16.40	.03	.26	+ 2.00	20.00	(1)	20.00	.90	7.66	+ 2.20	19.80	1.90	17.90

[1] Less NH_3 than in control.

[2] More NH_3 present than accounts for the change in acidity.

TABLE 2.—*Alkali production in skim milk incubated at 30° C.*—Continued.

Culture No.	7 days.						14 days.						30 days.					
	C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.			C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.			C. c. N/40 H_2SO_4 neutralized by NH_3 from 5 c. c.	NH_3 milligrams in 100 c. c.	Acidity in 100 c. c.	Reduction of acidity.		
				Change from control.	Due to NH_3.	Due to Na_2CO_3 or $NaHCO_3$.				Change from control.	Due to NH_3.	Due to Na_2CO_3 or $NaHCO_3$.				Change from control.	Due to NH_3	Due to Na_2CO_3 or $NaHCO_3$.
	C. c.	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*	*Mg.*	*C. c.*	*C. c.*	*C. c.*	*C. c.*
118	0.27	2.30	+ 1.80	20.20	(1)	20.20	0.47	4.00	+ 2.00	20.00	(1)	20.00	0.61	5.19	+ 1.60	20.40	0.45	19.95
119	.12	1.02	+ 8.20	13.80	(1)	13.80	.02	.17	+ 2.60	19.40	(1)	19.40	.72	6.13	+ 3.00	19.00	1.00	18.00
120	.47	4.00	+ 5.20	16.80	(1)	16.80	1.22	10.39	+ 2.80	19.20	3.61	15.59	2.16	18.39	+ 8.40	13.60	8.21	5.39
121	.76	6.47	+ 9.20	12.80	1.30	11.50	.48	4.09	+ 6.00	16.00	(1)	16.00	.20	1.70	+ 4.00	18.00	(1)	18.00
122	.72	6.13	+ 3.00	19.00	1.10	17.90	.67	5.70	+ 2.40	19.60	.85	18.75	1.00	8.52	+ 3.20	18.80	2.41	16.39
123	.46	3.92	+ 5.20	16.80	(1)	16.80	1.13	9.60	+ 9.60	12.40	3.15	9.25	2.19	18.65	+19.00	3.00	8.36	(2)
124	.25	2.13	+ 4.00	18.00	(1)	18.00	.46	3.92	+ 3.20	18.80	(1)	18.80	.71	6.05	+ 3.80	18.20	.95	17.25
125	.05	.43	+ 2.80	19.20	(1)	19.20	.34	2.90	+ 3.60	18.40	(1)	18.40	.92	7.83	+ 3.20	18.80	2.00	16.80
126	.13	1.11	+ 4.00	18.00	(1)	18.00	.58	4.94	+ 4.60	17.40	.40	17.00	.92	7.83	+ 3.40	18.60	2.00	16.60
128	.15	1.28	+ 2.80	19.20	(1)	19.20	.20	1.70	+ 3.00	19.00	(1)	19.00	.22	1.87	+ 2.20	19.80	(1)	19.80
130	.04	.34	+ 2.40	19.60	(1)	19.60	.43	3.66	+ 2.80	19.20	(1)	19.20	.80	6.81	+ 2.60	19.40	1.40	18.00
131	.10	.85	+10.00	12.00	(1)	12.00	.14	1.19	+ 2.80	19.20	(1)	19.20	.80	6.81	+ 3.00	19.00	1.40	17.60
132	.34	2.90	+ 3.00	19.00	(1)	19.00	.77	6.56	+ 4.40	17.60	1.35	16.25	1.33	11.33	+ 5.00	17.00	4.06	12.94
133	.60	5.11	+ 5.60	16.40	.50	15.90	.43	3.66	+ 2.60	19.40	(1)	19.40	.47	4.00	+ 3.00	19.00	(1)	19.00
134	.62	5.27	+ 6.20	15.80	.59	15.21	.56	4.77	+ 5.00	17.00	.30	16.70	.50	4.26	+ 2.60	19.40	(1)	19.40
135	.16	1.36	+ 2.60	19.40	(1)	19.40	.30	2.55	+ 3.20	18.80	(1)	18.80	.61	6.19	+ 4.20	17.80	.45	17.35
136	.56	4.77	+ 4.40	17.60	.30	17.30	.72	6.13	+ 5.00	17.00	1.10	15.90	1.22	10.39	+ 5.40	16.60	3.51	13.09
137	.20	1.70	+15.00	7.00	(1)	7.00	.12	1.02	+13.60	8.40	(1)	8.40	.32	2.72	+39.60	.....	(1)	(3)
138	.37	3.15	+11.20	10.80	(1)	10.80	.47	4.00	+ 3.70	18.30	(1)	18.30	.93	7.92	+ 3.20	18.80	2.05	16.75
139	.25	2.13	+ 3.00	19.00	(1)	19.00	.65	5.53	+ 3.60	18.40	.75	17.65	1.16	9.88	+ 3.60	18.40	3.21	15.19
140	.36	3.06	+ 8.80	13.20	(1)	13.20	.08	.68	+ 3.40	18.60	(1)	18.60	.90	7.66	+ 3.60	18.40	1.90	16.50
141	.23	1.96	+13.00	9.00	(1)	9.00	.16	1.36	+ 7.20	14.80	(1)	14.80	.59	5.02	+17.80	4.20	.35	3.85
142	.18	1.53	+ 3.00	19.00	(1)	19.00	.45	3.83	+ 3.40	18.60	(1)	18.60	.81	6.90	+ 3.40	18.60	1.45	17.15
143	.27	2.30	+ 5.40	16.60	(1)	16.60	1.08	9.20	+ 6.80	15.20	2.91	12.29	2.35	20.01	+16.20	5.80	9.16	(2)
144	.27	2.30	+10.80	11.20	(1)	11.20	.12	1.02	+ 3.20	18.80	(1)	18.80	.93	7.92	+ 1.00	21.00	2.05	18.95

145	.14	1.19	+10.60	11.40	(1)	11.40	.56	4.77	+ 3.80	18.20	.30	17.90	.93	7.92	+ 2.20	19.80	2.05	17.75
146	(1)	(1)	+ 9.40	12.60	(1)	12.60	(1)	(1)	+ 2.80	19.20	(1)	19.20	.53	4.51	+ 2.40	19.60	.05	19.55
147	.38	3.24	+ 2.60	19.40	(1)	19.40	.42	3.58	+ 2.80	19.20	(1)	19.20	.87	7.41	+ 2.60	19.40	1.75	17.65
303	.21	1.79	+ 3.00	19.00	(1)	19.00	.24	2.04	+ 3.40	18.60	(1)	18.60	.34	2.90	+ .80	21.20	(1)	21.20
309	.19	1.62	+ 3.20	18.80	(1)	18.80	.33	2.81	+ 2.20	19.80	(1)	19.80	.37	3.15	+ 1.40	20.60	(1)	20.60
314	.19	1.62	+ 2.00	20.00	(1)	20.00	.21	1.79	+ 4.00	18 00	(1)	18.00	.55	4.68	+ 6.80	15.20	.15	15.05
317	.14	1.19	+ 5.80	16.20	(1)	16.20	.47	4.00	+ 1.80	20.20	(1)	20.20	.44	3.75	+ 1.60	20.40	(1)	20.40
319	.30	2.55	+ 3.20	18.80	(1)	18.80	.38	3.24	+ 1.70	20.30	(1)	20.30	.32	2.72	+ 1.80	20.20	(1)	20.20
321	.16	1.36	+ 3.00	19.00	(1)	19.00	.22	1.87	+ 2.20	19.80	(1)	19.80	.20	1.70	+ 2.00	20.00	(1)	20.00
322	.25	2.13	+ 2.20	19.80	(1)	19.80	.20	1.70	+ 1.80	20.20	(1)	20.20	.39	3.32	+ 1.60	20.40	(1)	20.40
325	.34	2.90	+ 2.40	19.60	(1)	19.60	.35	2.98	+ 2.20	19.80	(1)	19.80	.26	2.21	+ 1.60	20.40	(1)	20.40
326	.32	2.72	+ 2.20	19.80	(1)	19.80	.32	2.72	+ 1.60	20.40	(1)	20.40	.27	2.30	+ 2.20	19.80	(1)	19.80
340	.41	3.49	+ 3.40	18.60	(1)	18.60	.30	2.55	+ 1.80	20.20	(1)	20.20	.42	3.58	+ 2.00	20.00	(1)	20.00
353	.27	2.30	+15.00	7.00	(1)	7.00	.06	.51	+ 5.00	17.00	(1)	17.00	.49	4.17	+ 0.00	22.00	(1)	22.00
354	.31	2.65	+ 6.80	15.20	(1)	15.20	.63	5.36	+ 2.60	19.40	.65	18.75	.86	7.32	+ 3.00	19.00	1.70	17.30
356	.37	3.15	+ 2.60	19.40	(1)	19.40	.36	3.06	+ 1.60	20.40	(1)	20.40	.29	2.47	+ 2.40	19.60	(1)	19.60
361	.32	2.72	+ 3.00	19.00	(1)	19.00	.32	2.72	+ 1.60	20.40	(1)	20.40	.31	2.54	+ 1.20	20.80	(1)	20.80
362	.75	6.39	+ 4.40	17.60	1.25	16.35	.52	4.43	+ 1.80	20.20	.10	20.10	.34	2.90	+ 1.60	20.40	(1)	20.40

[1] Less NH_3 than in control.

[2] More NH_3 present than accounts for the change in acidity.

[3] Milk more acid than control.

The results of the 14-day incubation are similarly shown in this table. It will be noticed that the alkaline change in 46 of the 68 cultures was due entirely to the formation of alkaline carbonates and in the other 22 to the presence of carbonates and ammonia. In almost every case the reduction in acidity was due largely to carbonates and at the same time there was a considerable increase in the amount of ammonia over that produced after 7 days' incubation. Culture 107 after 14 days' incubation showed a smaller reduction of acidity than after the 7-day period, indicating that there was a secondary acid fermentation.

After 30 days' incubation the reduction in acidity in 24 cultures was due entirely to formation of carbonates or bicarbonates, there being no increase in ammonia over that contained in the control tube of skimmed milk. In 37 cultures the alkaline change was due to the combined action of carbonates and ammonia. It will be seen, however, that in most cases the greater part of the change was due to the alkaline carbonates. In general there was an increase in the quantity of ammonia, found after 30 days, over that present at the end of the 7 and 14 day incubations. Cultures 107 and 137 after 30 days' incubation were found to be more acid than the control cultures. Both these cultures showed an alkaline change after 7 and 14 days' incubation. In cultures 10, 12, 49, 113, 123, and 143 an excess of ammonia was found over that necessary to produce the alkaline change, which showed that there must have been a secondary acid fermentation. This is further substantiated by the fact that these cultures showed a smaller change in alkalinity compared with the control after the 30-day incubation than they did at the end of the 7 or 14 day incubation.

The results of the work shown in Table 2 are summarized in Table 3.

TABLE 3.—*Cultures grouped according to reaction and cause of alkali production in skim milk.*

Incubation 30° C.	Reduction of acidity due to—		Increase of acidity over control.
	Ammonia and alkaline carbonate.	Alkaline carbonate.	
Days.	*Number of cultures.*	*Number of cultures.*	*Number of cultures.*
7	10	58	0
14	22	46	0
30	[1] 37	24	2

[1] Seven ammonia and no alkaline carbonate.

This summary needs no discussion since it simply presents data which have already been discussed. These results lead to the belief

which was previously stated, namely, that the alkali-forming bacteria produce an alkaline change in milk, due primarily to the formation of carbonates or bicarbonates, resulting from the oxidation of citric acid. After a long period of incubation there is a small amount of ammonia formed by certain cultures to which may be attributed a small part of the alkaline change in reaction of milk.

A third reason to substantiate the belief that the alkaline reaction in milk produced by the alkali-forming bacteria is due to the production of alkaline carbonates from the salts of organic acids. This will be discussed in detail later. The essential point of the production of an alkaline reaction during the fermentation of the organic-acid salts and the one upon which the other adjustments of equilibrium depend is the replacement of the relatively strong organic acids by the relatively weak carbonic acid.

SOURCES OF THE ALKALI-FORMING BACTERIA.

The alkali-forming bacteria which are under discussion in this paper were isolated largely from market milk, a few being obtained from the ice cream. Milk, however, can not be considered a source of any bacteria for it is merely a conveyor in which they may grow after being introduced through contamination. While alkali-forming bacteria are commonly found in market milk they must be introduced at some stage in its history and must, therefore, have a source.

Numerous samples of soil were first examined and then plated on extract agar and incubated at 30° C. for 5 days, at which time each colony was picked off and inoculated into litmus-milk tubes. These tubes were incubated at 30° C. for 14 days, after which they were examined for the characteristic reaction produced by bacteria of the alkali group. An alkaline reaction in litmus-milk tubes after 14 days' incubation without any sign of peptonization was found to be a practically certain test for the alkali-forming group of bacteria.

All the samples of soil examined showed the presence of large numbers of alkali-forming bacteria. These organisms were found also in water from shallow and deep wells, springs, and drains. Since they are present in soil it is only natural to expect to find them in water. An examination of the bacteria on the hands of farm laborers showed as high as 12,000,000 of the alkali-forming group of bacteria, this being the approximate number distributed over both hands. The organisms in this case in all probability came from soil.

Alkali-forming bacteria were not found in the udder and teats of cows in very large numbers, since an examination of 57 samples of milk drawn into sterile tubes from 15 different cows showed their presence in only 10 cases. The highest number found in any case was 30 per cubic centimeter. These organisms were present, how-

ever, in cow feces, being found in 8 out of 14 samples examined and and they comprised about 2.7 per cent of the total bacteria. Brushings from the udders and flanks of cows also showed the presence of the organisms. Alkali-forming bacteria were also found in very large numbers in unsterilized milk pails and cans. In one examination of a 10-gallon unsterilized milk can which was about to be filled with milk, approximately 144,000,000 of these organisms were found.

From extensive studies as to the sources of the alkali-forming bacteria found in milk it is believed that they are primarily soil organisms. The fact that alkali-forming bacteria are present in soil is further supported by the work of Temple (11), who states as a result of his experiments that "It is clear that soil bacteria can use sodium or potassium salts of organic acids in such a way as to have one of the products sodium or potassium carbonate." Soil, however, can not be considered the only source of the alkali-forming group of bacteria, for there are probably many organisms from other sources which might fall into this group based on their characteristic milk reaction.

MORPHOLOGY AND GROWTH.

In the study of the alkali-forming bacteria no elaborate morphological determinations of the organisms were made. Microscopic examination of 24-hour-old agar cultures showed that of 69 cultures 6 were cocci and 62 bacilli. In individual cultures the rod-shaped organisms varied greatly in size and for that reason it was not considered advisable to subdivide this group further according to their morphological characteristics. None of the organisms were spore formers.

The optimum temperature of this group of alkali-forming bacteria isolated from milk was found to be between 20° and 30° C., and within this range they grew vigorously. There was some growth below 20° C., but only slight growth above 30° C. In fact, 8 of the cultures, when streaked on agar and incubated at 37° C. for 48 hours, showed no growth, and 1 culture, No. 354, when inoculated into milk and inoculated at 37° C., rapidly died out, so that on the ninth day upon plating 1 cubic centimeter of this milk culture, no colonies appeared on the plates. The organisms grew best under aerobic conditions, but could also develop anaerobically on certain media. No growth was observed under anaerobic conditions in a synthetic medium containing sodium-ammonium phosphate as a source of nitrogen and the salt or an organic acid as the only source of carbon. The majority of this group of organisms appeared on agar plants as a moist, white growth, but there were 6 fluorescent, 2 pink, and 1 yellow culture in the collection. The most noticeable feature of the

white growth was its consistence, about 60 per cent of the cultures producing a slimy, viscous growth that was almost impossible to remove with a needle. In litmus milk these cultures produced a typical blue coloration which usually appeared in from 3 to 5 days when incubated at 30° C. Only 3 cultures out of the 68 were found to liquefy gelatin on incubation for 45 days at 20° C. The thermal death point of the alkali-forming organisms varied from 60° to 65.6° C., when heated in milk tubes for half an hour.

SOURCES OF NITROGEN.

From preliminary results of fermentation tests with the alkali-forming bacteria, it was evident that nitrogen should be supplied in some simple form, free from carbon. It was found that sodium-ammonium phosphate could be used as a source of nitrogen. This compound gave such satisfactory results that it was used throughout the work, carbon being supplied by other substances, as carbohydrates or organic acid salts. The alkali-forming bacteria were also able to utilize nitrogen from sodium nitrate and sodium nitrite, when a suitable source of carbon was present. With these two sources of nitrogen uniform results could not be obtained, for often a culture which would grow well on one inoculation would fail to develop at another time. The more complex nitrogen-containing substances were not suitable for fermentation tests, for reasons which will be discussed. All the organisms studied grew readily with asparagin as a source of nitrogen. It was not satisfactory, however, because ammonia was liberated, which interfered with the measurement of the fermentation test substances. Similar objections also apply to the use of beef extract. This not only supplied nitrogen but carbon as well. All the cultures grew vigorously in a solution of 0.2 per cent beef extract and 0.2 per cent sodium-dibasic phosphate and produced an alkaline reaction due probably to the formation of alkaline carbonates from the organic-acid salts present in the extract. It was, therefore, quite evident that beef extract was not a suitable source of nitrogen for use in fermentation tests when a definite fermentation was to be measured.

Other nitrogen-containing substances, such as peptone, gelatin, casein, and urea were good sources of nitrogen when carbon was supplied in some other form, but as sources of both nitrogen and carbon they were unsatisfactory. In other words, they are good sources of nitrogen but poor sources of carbon.

In studying the physiology of bacteria, it is believed that the sources of nitrogen should be given considerable thought, and whenever possible a simple compound free from carbon should be selected. For the alkali-forming bacteria sodium-ammonium phosphate fulfilled this requirement.

FERMENTATION OF CARBOHYDRATES.

DEXTROSE.

In some previous work with a small number of cultures of alkali-forming bacteria, it was found by Ayers and Johnson (2) that while they apparently did not ferment sugars, an alkaline reaction was usually produced. In recent work, however, with a larger number of cultures it has been found that certain carbohydrates were fermented but that special means have to be taken to determine this action.

Extract broth is not always a suitable medium in which to determine the fermentation of dextrose, as is shown by the results in Table 4. The broth had the following composition: Dextrose 1.0 per cent, beef extract 0.4 per cent, peptone 1.0 per cent, and distilled water. The reaction was brought to the neutral point, the solution filtered, the dextrose added, and the medium sterilized. The final reaction was about plus 0.2 (Fuller's scale). The cultures were incubated at 30° C. for 7 days and a duplicate set for 21 days, and titrated at the end of each incubation period. The figures in the table represent the change in titration from the control, 10 cubic centimeters of medium being titrated with tenth-normal sodium hydrate. The fermentation was considered positive when 1 per cent or more normal acid was formed, since this is the usual amount considered to indicate fermentation. An examination of the results shows that after 7 days' incubation 15 of the cultures showed an acid fermentation in dextrose and 10 showed such a reaction after 21 days. With 13 of the cultures a higher acidity was found after 7 days than after 21 days, while 7 showed more acid after the longer incubation. After 7 days' incubation 3 of the cultures were acid but after 21 days were alkaline, while 3 other cultures were alkaline after 7 days and became acid after 21 days. It will be noted in Table 4 that 3 cultures produced gas from dextrose. These results show that the fermentation of dextrose by the alkali-forming group of organisms was very indefinite when determined in the ordinary manner by titration in the regular broth medium. Some cultures showed a distinct and others only a slight fermentation, while many produced only an alkaline reaction.

As previously noted, it was found that these bacteria produced alkaline reaction when grown in beef-extract broth without sugar. The broth contained 0.2 per cent beef extract and 0.5 per cent sodium-dibasic phosphate. While this is not exactly the same composition as that of the dextrose-extract broth, the results of titrations help to explain some of the peculiar results obtained in the dextrose fermentation, and they are incorporated in Table 4. It may be seen that all the cultures of this group gave an alkaline change in titration after 14 days' incubation in beef-extract broth;

consequently this alkali formation would interfere with the reaction as a means for determining the dextrose fermentation.

TABLE 4.—*Reaction produced by the alkali-forming bacteria in dextrose and plain-extract broth.*

Culture No.	Dextrose-extract broth.		Beef-extract broth, 14 days.	Culture No.	Dextrose-extract broth.		Beef-extract broth, 14 days.
	7 days.	21 days.			7 days.	21 days.	
	C. c.	*C. c.*	*C. c.*		*C. c*	*C. c.*	*C. c.*
10	+2.40	+1.46	−0.39	128	+1.40	−0.86	−0.37
12	+ .66	+1.40	− .43	130	− .84	− .92	− .39
31	− .04	+ .82	− .29	131	− .56	− .90	− .38
49	+2.40	+ .78	− .41	132	− .76	− .82	− .32
59	+1.60	− .96	− .37	133	[2]+5.36	[2]+2.72	[2]− .40
60	−1.00	− .84	− .38	134	[2]+4.44	[2]+4.76	[2]− .35
61	− .64	− .88	− .40	135	− .88	− .92	− .39
62	− .94	− .86	− .36	136	− .76	− .82	− .37
66	− .90	− .70	− .30	137	+1.12	+2.88	− .39
72	− .06	− .20	− .30	138	− .88	− .98	− .32
73	− .60	− .74	− .30	139	− .86	− .94	− .42
101	− .94	− .84	− .29	140	−1.00	− .80	− .29
102	− .88	− .90	− .30	141	+2.56	+ .76	− .62
103	− .58	− .80	− .28	142	− .80	− .86	− .25
104	− .86	− .74	− .38	143	+ .93	+ .44	− .33
105	− .94	− .84	− .32	144	− .60	− .84	− .34
106	− .80	− .88	− .42	145	− .50	−1.06	− .39
107	+1.10	+2.46	− .41	146	− .84	− .96	− .39
108	− .74	− .80	− .41	147	−1.00	− .88	− .32
111	− .86	− .90	− .40	303	− .72	− .76	− .32
112	+3.00	+ .76	− .49	309	− .26	− .86	− .23
113	+2.08	+1.58	− .40	314	− .20	+ .94	− .47
114	− .80	− .82	− .29	317	− .52	− .76	− .32
116	− .82	− .76	− .31	319	+1.54	− .48	− .44
117	− .50	− .94	− .39	321	− .44	− .20	− .42
118	− .90	− .96	− .35	322	− .30	+1.66	− .41
119	− .80	− .82	− .39	325	− .50	− .16	− .44
120	+1.94	+ .42	− .42	326	− .40	− .32	− .38
121	[2]+5.60	[2]+4.46	− .28	340	− .90	− .70	− .31
122	− .70	− .96	− .38	353	− .70	− .80	− .53
123	+1.86	+1.70	− .37	354	− .84	− .84	− .38
124	− .86	− .94	− .32	356	− .50	− .52	− .35
125	− .64	− .90	− .34	361	− .16	.....	− .43
126	− .64	− .80	− .34	362	− .40	− .34	− .37

Minus (−) signs indicate an alkaline change[1] in titration.
Plus (+) signs indicate an acid change in titration.

[1] Change from control, in c. c. N/10 NaOH titrating 10 c. c. of medium. [2] Produced gas.

In order to avoid the complicating alkaline fermentation in extract broth, synthetic media were prepared which consisted of sodium-ammonium phosphate as the only source of nitrogen with dextrose as the only source of carbon. The media used had the following composition:

		Medium A.	Medium B.	Medium C.
Sodium-ammonium phosphate	grams	2.0	1.5	1.0
Dextrose	do	10.0	3.0	10.
Potassium chlorid	do	.1	.1	.2
Distilled water	cubic centimeter	1,000	1,000	1,000

The results of the fermentation of the dextrose in these media are shown in Table 5. The change in the hydrogen-ion concentration during 14 days' incubation was used as a measure of the fermenta-

tion. It will be noted that in medium A, 25 cultures showed a distinct fermentation of dextrose, the hydrogen-ion concentration in most cases going from P_H 6.9 (control) to P_H 4.5, a few cultures reached about P_H 6.0, and only 19 cultures changed from P_H 6.9 to P_H 6.5 or lower. These cultures it was believed fermented dextrose but were called plus or minus.

TABLE 5.—*Results of fermentation of dextrose in synthetic media with different buffer contents.*

Culture No.	Medium A.		Medium B.		Medium C.		Summary of dextrose fermentation.	Culture No.	Medium A.		Medium B.		Medium C.		Summary of dextrose fermentation.
	P_H.	Dextrose fermentation.	P_H.	Dextrose fermentation.	P_H.	Dextrose fermentation.			P_H.	Dextrose fermentation.	P_H.	Dextrose fermentation.	P_H.	Dextrose fermentation.	
Control..	6.9	.....	7.2	.....	6.8	.....	.....	Control..	6.9	.....	7.2	.....	6.8	.....	.....
10	4.5	+	5.5	+	.....	.....	+	130	6.9	−	7.2	−	.....	.....	−
12	4.5	+	5.4	+	.....	.....	+	131	6.6	±	7.2	−	5.3	+	+
31	5.7	+	6.2	+	.....	.....	+	132	6.6	±	7.2	−	5.0	+	+
49	4.5	+	5.4	+	.....	.....	+	133	4.5	+	6.2	+	.....	.....	+
59	6.9	−	7.2	−	.....	.....	−	134	4.5	+	6.2	+	.....	.....	+
60	6.9	−	7.2	−	.....	.....	−	135	6.7	±	7.2	−	5.2	+	+
61	6.9	−	7.2	−	.....	.....	−	136	6.5	±	7.2	−	5.0	+	+
62	6.9	−	7.2	−	.....	.....	−	137	4.5	±	5.0	+	.....	.....	+
66	6.9	−	7.2	−	.....	.....	−	138	6.6	±	7.2	−	5.3	+	+
72	5.8	+	6.2	+	.....	.....	+	139	6.9	−	7.2	−	.....	.....	−
73	6.9	−	7.2	−	.....	.....	−	140	6.5	±	7.2	−	5.0	+	+
101	6.6	±	7.2	−	4.9	+	+	141	4.5	+	6.0	+	.....	.....	+
102	6.6	±	7.2	−	5.3	+	+	142	6.9	−	7.2	−	.....	.....	−
103	6.9	−	7.2	−	.....	.....	−	143	4.5	+	5.4	+	.....	.....	+
104	6.7	±	7.2	−	5.8	+	+	144	6.6	±	7.2	−	5.0	+	+
105	6.6	±	7.2	−	5.4	+	+	145	6.9	−	7.2	−	.....	.....	−
106	6.9	−	7.2	−	.....	.....	−	146	6.6	±	7.2	−	5.0	+	+
107	4.5	+	5.5	+	.....	.....	+	147	6.9	−	7.2	−	.....	.....	−
108	6.5	±	7.2	−	4.8	+	+	303	6.9	−	7.2	−	.....	.....	−
111	6.9	−	7.2	−	.....	.....	−	309	6.9	−	7.2	−	.....	.....	−
112	4.5	+	6.0	+	.....	.....	+	314	5.6	+	6.3	+	.....	.....	+
113	4.5	+	5.5	+	.....	.....	+	317	6.9	−	7.2	−	.....	.....	−
114	6.9	−	7.2	−	.....	.....	−	319	6.2	+	6.5	+	5.2	+	+
116	6.7	±	7.2	−	6.3	+	+	321	6.2	+	6.3	+	5.3	+	+
117	6.6	±	7.2	−	5.0	+	+	322	6.2	+	6.4	+	5.3	+	+
118	6.9	−	7.2	−	.....	.....	−	325	6.2	+	6.5	+	5.2	+	+
119	6.7	±	7.2	−	5.9	+	+	326	6.2	+	6.5	+	5.2	+	+
120	4.5	+	5.5	+	.....	.....	+	340	6.9	−	7.2	−	.....	.....	−
121	4.5	+	6.2	+	.....	.....	+	353	6.9	−	7.2	−	.....	.....	−
122	6.9	−	7.2	−	.....	.....	−	354	6.9	−	7.2	−	.....	.....	−
123	4.5	+	4.5	+	.....	.....	+	356	6.2	+	6.5	+	5.0	+	+
124	6.7	±	7.2	−	5.0	+	+	361	6.0	+	6.4	+	.....	.....	+
125	6.5	±	7.2	−	5.0	+	+	362	6.3	+	6.2	+	5.0	+	+
126	6.6	±	7.2	−	5.0	+	+								
128	6.9	−	7.2	−	.....	.....	+								

Medium B, while having less buffer than medium A, contained also less dextrose, and in it only 25 cultures showed a positive fermentation. Medium C was then tried and it contained the same amount of dextrose as medium A but half the sodium-ammonium phosphate. As this medium had considerably less buffer than medium A, it was expected that the cultures showing only a slight change in P_H in medium A would show a much larger change in medium C. This was found to be the case, as is shown in the table.

Only the cultures which showed a slight P_H change in medium A were run in medium C. From the results of the work it was evident that 44 of the 68 cultures of alkali-forming bacteria could ferment dextrose, but many of them to only a slight extent. The fermentation was slow with certain of the bacteria, as is seen in Table 6, which shows the P_H value of 3 cultures in medium A. These cultures represent 3 types of fermentation. Culture 12 reached P_H 4.5 after 3 days' incubation at 30° C., while culture 319 reached P_H 6.0 only after 10 days, and its highest hydrogen-ion concentration was P_H 5.5. Culture 140 reached P_H 6.5 in 10 days, which seemed to be its highest point, and did not show further change after 21 days' incubation.

TABLE 6.—*Three types of dextrose fermentations as shown by the hydrogen-ion concentration in terms of* PH.

Culture No.	Days.								
	1	2	3	4	5	7	10	14	21
Control	7.1	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.9
12	6.6	5.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5
319	6.9	6.8	6.8	6.8	6.6	6.6	6.0	6.0	5.5
140	7.0	7.0	7.0	6.9	6.9	6.8	6.5	6.5	6.5

TABLE 7.—*Comparison of the fermentation of dextrose in an extract broth and a synthetic medium.*

Culture No.	Dextrose broth.		Dextrose-sodium-ammonium phosphate.	Culture No.	Dextrose broth.		Dextrose-sodium-ammonium phosphate.	Culture No.	Dextrose broth.		Dextrose-sodium-ammonium phosphate.
	7 days.	21 days.	14 days.		7 days.	21 days.	14 days.		7 days.	21 days.	14 days.
10	+	+	+	118	−	−	0	145	−	−	0
12	−	+	+	119	−	−	+	146	−	−	+
31	−	−	+	120	+	−	+	147	−	−	0
49	+	−	+	121	+	+	+	303	−	−	0
59	+	−	0	122	−	−	0	309	−	−	0
60	−	−	0	123	+	+	+	314	−	−	+
61	−	−	0	124	−	−	+	317	−	−	0
62	−	−	0	125	−	−	+	319	+	−	+
66	−	−	0	126	−	−	+	321	−	−	+
72	−	−	+	128	+	−	0	322	−	+	+
73	−	−	0	130	−	−	0	325	−	−	+
101	−	−	+	131	−	−	+	326	−	−	+
102	−	−	+	132	−	−	+	340	−	−	0
103	−	−	0	133	+	+	+	353	−	−	0
104	−	−	+	134	+	+	+	354	−	−	0
105	−	−	+	135	−	−	+	356	−	−	+
106	−	−	0	136	−	−	+	361	−	0	+
107	+	+	+	137	+	+	+	362	−	−	+
108	−	−	+	138	−	−	+				
111	−	−	0	139	−	−	0				
112	+	−	+	140	−	−	+				
113	+	+	+	141	+	−	+				
114	−	−	0	142	−	−	0				
116	−	−	+	143	−	−	+				
117	−	−	+	144	−	−	+				

Minus (−)=alkaline. Plus (+)=acid. Zero (0)=no change.

The results of the fermentation of dextrose in these simple synthetic media were so different from the fermentation in the complex extract-broth medium that the results are compared in Table 7. In the dextrose-broth medium incubated for 7 days, 15 cultures showed a production of at least 1 per cent normal acid and on this basis 10 cultures showed a dextrose fermentation in the same medium after 21 days' incubation, yet in the synthetic medium 44 of the 68 cultures fermented dextrose. The results indicate very clearly the inaccuracies which may occur in the study of the fermentation of test substances in complex media.

GALACTOSE.

The alkali-forming bacteria fermented galactose in a manner nearly identical with dextrose. Practically all the cultures which fermented dextrose fermented galactose and, in fact, reached about the same hydrogen-ion concentration in the synthetic medium.

LACTOSE, SACCHAROSE, AND RAFFINOSE.

Lactose is not fermented in the ordinary beef-extract medium when measured by the usual titration methods or by the change in hydrogen-ion concentration. The assumption that the alkali-forming bacteria are nonlactose fermenters based on results of the fermentation of the sugar in ordinary media is quite incorrect, as is shown in Table 8. It was found that 11 of the cultures showed a slight change in hydrogen-ion concentration in synthetic medium A. Medium A and medium C were the same as previously described except that lactose was substituted for dextrose. The slight fermentation of lactose was more clearly indicated by the results obtained with medium C. There is included also in the table the reaction of skim-milk cultures of the organisms after 7, 14, and 30 days' incubation at 30° C. In every case the acidity decreased during the first 7 days and then increased. After 14 days the acidity in all but 3 cultures was higher than on the seventh day, while in 30 days all the cultures showed a marked increase in acidity compared with that of the seventh day.

The acid formation, which is probably secondary in milk, correlates perfectly with the cultures which showed a slight fermentation of lactose in the synthetic media. All the cultures which showed no indication of fermentation of lactose in the sodium-ammonium-phosphate medium failed to show any secondary acid formation in milk during a period of 30 days.

Saccharose was found to be fermented by only 2 of the cultures, Nos. 31 and 72. In a synthetic medium these change the reaction from P_H 7.1 to P_H 6.5 and 6.6, respectively. This indicates only a slight fermentation.

Raffinose was not fermented by any of the cultures even when several of the different media were used.

TABLE 8.—*The cultures which fermented lactose in synthetic media and the milk reactions by titration of the same cultures.*

Culture No.	Lactose synthetic media.		Reaction of milk[1] cultures after—		
	A.	C.	7 days.	14 days.	30 days.
	P_H.	P_H.	*C. c.*	*C. c.*	*C. c.*
Control	6.9	6.8	22.0	22.0	22.0
10	6.7	6.1	2.0	10.6	17.0
12	6.7	6.1	2.8	7.4	15.4
49	6.7	6.1	4.6	7.0	12.8
107	6.7	4.8	10.2	21.0	45.2
112	6.7	6.4	5.6	6.6	10.2
113	6.7	6.4	3.0	7.8	15.8
120	6.6	6.4	5.2	2.8	8.4
123	6.7	6.0	5.2	9.6	19.0
137	6.6	5.9	15.0	13.6	39.6
141	6.7	6.3	13.0	7.2	17.8
143	6.7	6.1	5.4	6.8	16.2

[1] 100 c. c. of milk titrated with tenth-normal NaOH.

In the study of the fermentation of sugars by the alkali-forming bacteria care must be exercised to use a medium in which organic-acid salts are not present, for they are readily oxidized to alkaline carbonates, which may mask an acid fermentation of the sugar. A synthetic medium is of the greatest assistance in this connection.

FERMENTATION OF ALCOHOLS.

In a study of the fermentation of sugars it is customary to include some of the polyatomic alcohols, such as adonite, dulcite, mannite, and glycerin. It was found that these polyatomic alcohols were not particularly good sources of carbon for the alkali group of organisms when used in a synthetic medium composed of sodium-ammonium phosphate 2 grams, potassium chlorid 0.1 gram, test alcohol 2 grams, and distilled water 1,000 cubic centimeters. None of the cultures fermented adonite or dulcite, but, as is shown in Table 9, 5 cultures fermented mannite and 3 fermented glycerin. In mannite the maximum change in hydrogen-ion concentration was from P_H 7.1 (control) to P_H 6.1 and in glycerin from P_H 6.9 (control) to P_H 6.4.

The monoatomic alcohols are not commonly used as test fermentation substances, but it was thought advisable to determine whether some of them could supply carbon for the alkali-forming bacteria. Four of the monoatomic alcohols, namely, methyl, ethyl, propyl, and amyl, were tested with different amounts in the sodium-ammonium phosphate medium just described. As nothing was known regarding the effect of different concentrations of these alcohols on the bacteria, 3 different sets of media with 10, 5, and 3 grams, respectively, of alcohol to the liter were used. The cultures were incubated 7 days at 30° C. and any change over P_H 0.2 in a hydrogen-ion

concentration was considered a positive fermentation. Methyl alcohol was not fermented by any of the cultures, which may be due to the poisonous character of this alcohol. As may be seen from Table 9, the majority of the cultures fermented propyl alcohol. Forty-eight of the 68 cultures fermented both propyl and ethyl alcohol when 5 grams of alcohol per liter was used in the medium. It will be noted that with the other quantities of alcohol more cultures fermented the propyl than the ethyl alcohol. Amyl alcohol was not so readily fermented.

In ethyl alcohol the maximum hydrogen-ion change was from P_H 7.1 (control) to P_H 5.7, in propyl alcohol from P_H 7.0 (control) to P_H 5.4, and in amyl alcohol from P_H 6.9 (control) to P_H 6.6. While there was not much difference between the fermentation when 10 grams and 5 grams of alcohol were used per liter, a larger number of cultures fermented the alcohol in these cases than when only 3 grams was used. In general, when a culture fermented ethyl it fermented propyl alcohol, but this was not true in all cases. Usually when amyl alcohol was fermented ethyl and propyl were fermented also, but there were several exceptions. Only one of the cultures which fermented mannite also fermented the monoatomic alcohols. Cultures 121, 133, and 134, which fermented glycerin, were not able to ferment any of the monoatomic alcohols.

TABLE 9.—*Fermentation of the alcohols.*

Culture No.	Ethyl, grams per liter.			Propyl, grams per liter.			Amyl, grams per liter.			Mannite.	Glycerin.
	10	5	3	10	5	3	10	5	3		
10	−	−	−	−	−	−	−	−	−	−	−
12	−	−	−	−	−	−	−	−	−	−	−
31	−	+	+	−	+	+	+	−	−	+	−
49	−	+	+	−	+	+	+	−	−	−	−
59	+	+	−	+	+	+	−	−	+	−	−
60	+	+	+	+	+	+	+	+	+	−	−
61	+	+	−	+	+	+	+	−	−	−	−
62	−	−	−	+	+	+	+	−	−	−	−
66	+	+	−	+	+	+	+	+	+	−	−
72	−	−	−	−	−	−	−	−	−	+	−
73	+	+	−	−	−	−	−	−	−	−	−
101	+	+	−	+	+	+	−	−	−	−	−
102	+	+	−	+	+	+	−	−	−	−	−
103	−	−	−	−	−	−	−	−	−	−	−
104	−	−	−	+	+	+	−	−	−	−	−
105	−	−	+	+	−	−	−	−	−	−	−
106	+	+	−	+	+	+	+	+	+	−	−
107	−	+	−	−	+	+	−	−	−	−	−
108	+	+	−	+	+	+	−	−	−	−	−
111	+	+	+	+	+	+	+	+	+	−	−
112	−	+	−	−	−	−	−	−	−	−	−
113	−	+	−	+	+	−	−	−	+	−	−
114	+	+	−	+	+	+	−	−	−	−	−
116	−	+	−	+	+	+	−	−	−	−	−
117	+	+	−	+	+	+	−	−	−	−	−
118	+	+	+	+	+	+	+	−	+	−	−
119	−	+	−	+	+	+	+	−	−	−	−
120	−	−	−	−	−	−	−	−	−	−	−
121	−	−	−	−	−	−	−	−	−	+	+
122	+	+	−	+	+	+	+	+	+	−	−

TABLE 9.—*Fermentation of the alcohols*—Continued.

Culture No.	Ethyl, grams per liter.			Propyl, grams per liter.			Amyl, grams per liter.			Mannite.	Glycerin.
	10	5	3	10	5	3	10	5	3		
123	−	−	−	−	−	−	−	−	−	−	−
124	−	+	−	+	+	+	−	−	−	−	−
125	+	+	+	+	+	+	−	−	−	−	−
126	+	+	+	+	+	+	−	−	−	−	−
128	+	+	−	+	+	+	+	−	−	−	−
130	+	+	−	+	+	+	+	+	−	−	−
131	−	−	−	+	+	+	−	−	−	−	−
132	+	+	−	+	+	+	−	−	−	−	−
133	−	−	−	−	−	−	−	−	−	+	+
134	−	−	−	−	−	−	−	−	−	+	+
135	−	+	−	+	+	+	−	−	−	−	−
136	+	−	−	+	+	+	−	−	−	−	−
137	−	−	−	−	+	+	−	−	−	−	−
138	+	+	−	+	+	+	−	−	−	−	−
139	+	+	−	+	+	+	+	+	+	−	−
140	−	+	−	+	+	+	−	−	−	−	−
141	−	−	−	−	−	−	−	−	−	−	−
142	+	+	−	+	+	+	+	−	+	−	−
143	−	+	−	−	+	+	+	−	−	−	−
144	−	+	−	+	+	+	−	−	−	−	−
145	+	+	−	+	+	+	+	+	+	−	−
146	+	+	−	+	+	+	+	−	−	−	−
147	+	+	−	+	+	+	+	+	+	−	−
303	+	+	−	+	+	−	−	−	−	−	−
309	−	−	−	−	−	−	−	−	−	−	−
314	−	−	−	−	−	−	−	−	−	−	−
317	+	+	−	+	+	+	−	−	−	−	−
319	+	+	+	−	−	−	−	−	−	−	−
321	+	+	+	+	+	−	+	−	+	−	−
322	+	+	+	−	+	−	+	−	+	−	−
325	+	+	+	+	−	−	+	−	−	−	−
326	+	+	+	−	+	+	+	−	+	−	−
340	+	+	−	+	+	−	−	−	−	−	−
353	−	−	−	−	−	−	−	−	−	−	−
354	+	+	−	+	+	+	−	−	−	−	−
356	+	+	+	+	+	+	−	−	−	−	−
361	+	+	+	−	−	−	+	−	+	−	−
362	−	−	−	−	−	−	−	−	−	−	−
Total positive	37	48	15	43	48	43	24	9	16	5	3

NOTE.—No fermentation in the following alcohols—methyl, dulcite, adonite.

It is evident from these results that the polyatomic alcohols adonite, dulcite, mannite, and glycerin are satisfactory sources of carbon for the alkali-forming group of bacteria and were of no particular value in the study of the bacteria under discussion in this paper. On the other hand the monoatomic alcohols ethyl, propyl, and amyl were fermented by a larger number of cultures, and while the fermentations were relatively slight it is believed that they may be of some value in further studies of the alkali-forming bacteria.

FERMENTATION OF SALTS OF ORGANIC ACIDS.

It has been shown previously in this paper that the alkaline reaction in milk produced by the alkali-forming organisms was due to the oxidation of the salts of citric acid. Since these bacteria can ferment the salts of citric acid it seemed quite probable that other organic-

acid salts might be utilized as a source of carbon and thereby become valuable substances for fermentation tests.

In 1895 Maassen (7) studied the fermentation of 21 different organic-acid salts by 52 varieties of bacteria. He obtained some growth with all these cultures in media containing the various organic-acid salts. As Maassen used these salts in a medium containing peptone, it is not surprising that he obtained positive results with all the organic acids, for the reason that the carbon could probably have been obtained by the bacteria from either the organic acid or the peptone, according to which one was the more available. If these organic-acid salts are to serve as carbon-containing test substances they must be used in a medium containing no other source of carbon.

In order to determine the value of the salts of the organic acids as a source of carbon, the fermentation of 24 of these salts by the alkali-forming group of bacteria was studied. The fermentation was determined in a synthetic medium of the following composition:

$NaNH_4HPO$	gram	0.50
NaH_2PO_4	do	.17
KCl	do	.20
Water, distilled	c. c.	1,000
Acid (neutralized with NaOH)	grams	1.2

Urea and hippuric and uric acids were also used in the following media:

Urea	grams	2.00	Hippuric acid	gram	1.0	Uric acid	gram	1.0
Na_2HPO_4	gram	.50	NaOH quantity sufficient to neutralize the acid	gram	.50	NaOH	grams	8.00
KCl	do	.10	NaH_2PO_4	do	.17	KCl	gram	.10
NaH_2PO_4	do	.17	KCl	do	.10	Water, distilled	c.c.	1,000
Water, distilled	c.c.	1,000	Water	c. c.	1,000			
Filter through Berkefeld).								

It is evident from the composition of the medium that if growth occurs the carbon must be obtained from an organic-acid salt. The fermentation of the organic-acid salts was measured by the change in the hydrogen-ion concentration. A change of more than P_H 0.2 being recorded as a positive fermentation. An exception is taken in recording the results of the fermentation of butyric, valeric, and caproic acids where any change from the control is recorded as positive because of the possibility that these acids were split into simpler acids, and these simpler acids in turn oxidized to alkaline carbonates. The final hydrogen-ion concentration of the medium would in such cases depend upon the point in the fermentation at which it was determined. In every case a change in hydrogen-ion concentration from the control showed growth in the tubes. The complete result of the study is given in Table 10. It will be seen in the tabulated

results in the table that nearly all the organic-acid salts used were fermented to a greater or less extent. In the table are the results of hippuric and uric acids and urea, these substances being included merely for the sake of convenience; their fermentations will be discussed later.

Before proceeding with the fermentation of the salts of the organic acids it is necessary to call attention to the fact that the growth in the synthetic medium as used in this investigation with the organic-acid salts as a source of carbon was usually quite different in appearance from the growth obtained in the sugar broths. It was found that the alkali-forming bacteria frequently grew in a mass in the bottom of the tube and left the medium perfectly clear. Often when the greatest change in the hydrogen-ion concentration was noticed there was little appearance of growth in the tubes; at other times the medium became extremely cloudy.

In connection with the fermentation of these organic-acid salts an attempt has been made to determine from which radical or radicals the carbon was obtained. The organic acids are grouped, therefore, in Table 11 according to the radicals they contain. For example citric, malic, and lactic acids are grouped together for discussion because they contain a secondary or tertiary alcohol radical linked to a carboxyl and to a methyl radical.

It will be seen in Table 11 that all the 68 cultures studied were able to utilize carbon from the sodium salt of pyruvic acid. The table gives the structural formula of the different acids but it must be remembered that the sodium salt was employed. Pyruvic acid ($CH_3COCOOH$) comprises a ketone (CO) radical connecting a methyl (CH_3) and carboxyl (COOH). It seems that carbon was readily available from an acid of this structure. This acid was sterilized by passage through a Berkefeld filter so as to prevent decomposition by heat. The cultures also obtained their carbon readily from other oxyacids, such as citric, malic, and lactic. In such acids an alcohol radical connects the carboxyl to the methyl group, as illustrated by

lactic acid, $\begin{array}{c} CH_3 \\ | \\ CHOH \\ | \\ COOH \end{array}$. The cultures were able to obtain their carbon almost as well from salts of such acids as succinic, acetic, propionic, butyric, valeric, and caproic, in which there is no alcohol radical, but one methyl group is linked to a carboxyl.

TABLE 10.—*Complete results of the fermentations of the organic-acid salts and urea in terms of* P_H *values.*

Culture No.	Citric.	Malic.	Lactic.	Succinic.	Acetic.	Propionic.	Butyric.	Isobutyric.	α Oxybutyric.	β Oxybutyric.	Valeric.	Isovaleric.	Caproic.	Mucic.	Glyceric.	Tartaric.	Malonic.	Formic.	Benzoic.	Salicylic.	Hippuric.	Uric.	Urea.
Control	7.2	6.9	6.9	7.1	6.9	6.9	6.9	6.9	6.6	6.9	7.0	6.9	6.9	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	7.0
119	8.3	8.9	7.4	8.5	7.5	7.2	6.7	7.2	6.8	7.6	6.4	7.1	6.6	6.9	6.9	7.0	7.0	7.4	6.9	6.8	6.9	7.4	7.4
130	8.8	8.9	7.7	8.5	8.1	7.6	7.2	7.2	7.0	6.9	6.2	7.2	6.3	6.9	6.9	7.0	7.0	7.7	7.2	7.2	6.9	7.4	7.5
131	8.3	8.7	7.7	8.5	8.0	7.5	7.0	7.5	7.0	7.6	6.5	7.1	6.8	6.9	6.9	7.0	7.0	7.6	7.1	6.8	6.9	7.4	8.5
138	8.5	8.9	7.7	8.5	7.5	7.9	6.7	7.3	7.1	7.5	6.4	7.1	6.3	6.9	6.9	7.0	7.0	7.4	7.1	6.8	6.9	7.4	7.0
140	8.3	8.9	7.7	8.2	7.9	8.0	6.5	7.3	7.1	7.6	6.4	7.2	6.3	6.9	6.9	7.0	7.0	7.3	7.1	6.8	6.9	7.4	7.0
354	8.2	8.8	7.7	8.8	7.4	6.9	6.5	7.3	7.1	7.5	6.3	7.2	6.8	6.9	6.9	7.0	7.0	7.8	6.9	6.8	6.9	7.4	8.3
10	8.8	8.8	7.9	8.5	8.1	7.7	7.8	7.5	7.0	7.8	7.2	7.3	7.5	7.6	8.2	7.0	7.0	8.5	(1)	6.8	(1)	8.6	7.0
12	8.8	8.8	7.9	8.5	8.4	7.7	7.8	7.5	7.1	7.8	7.6	7.4	7.6	7.6	8.2	7.0	7.0	8.5	(1)	6.8	(1)	8.6	7.0
31	8.8	8.9	8.2	8.8	8.6	8.0	7.5	7.4	7.2	7.8	7.1	7.4	7.2	6.9	6.9	7.0	7.0	8.2	7.1	6.8	7.5	7.4	8.7
49	8.7	8.8	8.0	8.4	8.3	7.5	7.8	7.5	7.0	7.8	7.2	7.4	7.6	7.5	8.2	7.0	7.0	8.5	7.3	6.8	(1)	8.6	7.0
59	8.7	8.9	7.6	8.5	8.2	7.8	7.7	7.5	7.1	7.6	6.9	7.2	7.4	6.9	6.9	7.0	8.7	6.9	6.9	6.8	6.9	7.4	8.2
60	8.8	8.9	8.1	8.7	8.4	8.0	7.6	7.4	7.5	7.3	6.5	7.2	7.2	6.9	6.9	7.0	8.7	6.9	7.3	7.3	6.9	7.4	8.1
61	8.6	8.8	7.7	8.3	8.2	7.8	7.7	7.4	7.1	7.6	6.9	7.2	7.4	6.9	6.9	7.0	8.7	6.9	6.9	6.8	6.9	7.4	8.4
62	8.7	8.9	8.1	8.5	8.4	8.0	7.6	7.3	7.2	7.6	6.5	7.2	7.2	6.9	6.9	7.0	8.7	6.9	7.3	7.2	6.9	7.4	8.3
66	8.7	8.8	8.0	8.6	8.2	7.9	7.6	7.5	7.4	7.6	6.5	7.2	6.5	6.9	6.9	7.0	7.0	6.9	7.2	7.2	7.3	7.4	8.3
72	8.8	8.9	8.2	8.7	8.5	8.0	7.6	7.6	7.5	7.8	7.3	7.4	7.1	6.9	6.9	7.0	7.0	8.5	7.1	6.8	7.6	7.4	8.7
73	7.2	7.7	7.7	7.1	7.4	6.9	6.9	6.9	6.6	7.3	7.0	6.9	6.9	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	7.9
101	8.3	8.8	7.8	8.1	7.6	7.4	6.4	7.3	7.2	7.5	6.2	7.2	6.2	6.9	6.9	7.0	7.0	7.5	7.1	6.8	6.9	7.4	7.0
102	8.3	8.9	7.8	8.2	7.4	8.0	6.2	7.3	7.1	7.3	6.2	7.2	6.2	6.9	6.9	7.0	7.0	7.5	7.1	6.8	6.9	7.4	7.0
103	7.2	7.2	7.3	7.1	6.9	6.9	6.9	6.9	6.6	7.2	7.0	6.9	6.9	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	7.0
104	8.5	8.9	7.6	8.1	7.5	7.4	6.4	7.3	6.9	7.6	6.2	7.2	6.5	6.9	6.9	7.0	7.0	7.2	7.1	6.8	6.9	7.4	7.0
105	8.5	8.9	7.6	8.2	7.7	7.1	6.3	7.3	6.9	7.2	6.3	7.1	6.5	6.9	6.9	7.0	7.0	7.2	7.1	6.8	6.9	7.4	7.0
106	8.9	8.9	8.1	8.8	8.4	8.0	7.6	7.5	7.5	7.4	6.9	7.2	7.1	6.9	6.9	7.0	7.0	8.5	7.3	7.2	6.9	7.4	8.5
107	8.7	8.8	8.1	8.1	8.5	8.0	7.8	7.5	7.2	7.7	7.2	7.4	7.4	7.6	8.5	7.0	7.0	8.6	7.3	6.8	8.0	7.4	7.0
108	8.7	8.9	7.6	8.2	7.7	7.5	6.2	7.3	7.0	6.9	6.2	7.2	6.3	6.9	6.9	7.0	7.0	7.3	7.1	6.8	6.9	7.4	7.0
111	8.8	8.9	7.6	8.5	8.3	8.0	7.3	7.6	7.4	7.0	6.2	7.2	6.3	6.9	6.9	7.0	7.0	8.1	7.3	7.3	6.9	7.4	7.8
112	8.5	8.9	8.0	8.3	8.2	7.8	7.8	7.4	7.0	7.6	7.3	7.4	7.6	7.5	8.3	8.5	7.0	8.6	6.9	6.8	7.9	8.6	7.0
113	8.8	8.4	7.7	8.3	8.4	8.0	7.8	7.5	7.1	7.7	7.4	7.4	7.6	7.6	8.4	7.0	7.0	8.6	(1)	6.8	(1)	7.4	7.0
114	8.2	8.7	7.6	7.9	7.3	7.3	6.4	7.3	6.6	6.9	6.2	7.2	6.2	6.9	6.9	8.4	7.0	6.9	6.9	6.8	6.9	7.4	7.0
116	8.7	8.9	7.5	8.2	7.5	7.3	7.1	7.3	6.9	7.6	6.2	7.1	6.5	6.9	6.9	7.0	7.0	7.5	7.1	6.8	6.9	7.4	7.0
117	8.5	8.9	7.6	8.2	7.6	7.3	6.3	7.3	6.9	7.8	6.2	7.2	6.3	6.9	6.9	7.0	7.0	7.5	7.1	6.8	6.9	7.4	7.0
118	8.8	8.9	7.7	8.6	8.2	8.1	7.6	7.7	7.3	7.3	6.5	7.4	6.5	6.9	6.9	7.0	7.0	8.5	7.3	7.2	6.9	7.4	7.8
120	8.4	8.9	8.0	8.3	8.2	7.8	7.7	7.3	7.3	7.7	7.4	7.2	7.6	7.5	8.2	8.0	7.0	8.7	6.9	6.8	8.7	8.2	8.5
121	8.0	8.3	8.0	8.4	7.8	8.9	6.9	6.9	6.6	6.9	7.0	6.9	6.9	6.9	7.9	7.0	8.6	7.3	6.9	6.8	7.5	7.4	7.4
122	8.8	8.9	7.9	8.7	8.4	8.0	7.6	7.5	7.3	7.6	6.5	7.3	6.3	6.9	6.9	7.0	7.0	6.9	7.3	7.2	6.9	7.4	8.4
123	8.9	8.7	7.7	8.5	8.5	7.7	7.8	7.5	7.1	7.6	7.4	7.3	7.5	7.5	8.2	7.0	7.0	8.5	6.9	6.8	8.0	8.5	7.0
124	8.2	8.8	7.6	8.1	7.4	7.3	6.7	7.3	6.8	6.9	6.5	6.9	6.6	6.9	6.9	7.0	7.0	7.3	6.9	6.8	6.9	7.4	7.5

125	8.8	8.8	7.6	8.2	7.7	7.4	6.7	7.3	7.1	6.9	6.2	7.1	6.3	6.9	6.9	7.0	7.0	7.5	6.9	6.8	6.9	7.4	7.9
126	8.6	8.9	7.6	8.0	7.7	7.3	6.5	7.3	6.9	7.1	6.6	7.0	6.8	6.9	6.9	7.0	7.0	7.4	7.1	6.8	6.9	7.4	7.0
128	8.2	8.8	7.4	7.8	7.4	7.3	6.4	7.2	6.6	6.9	6.2	7.1	6.3	6.9	6.9	8.2	7.0	6.9	6.9	6.8	6.9	7.4	7.0
132	8.8	8.8	7.6	8.2	7.8	7.2	7.3	7.3	7.1	7.6	6.5	7.1	6.8	6.9	6.9	8.5	7.0	7.6	7.1	6.8	6.9	7.4	7.0
133	8.8	8.4	8.0	8.2	8.4	6.9	6.9	6.9	6.6	6.9	7.0	6.9	6.9	6.9	8.2	7.0	8.5	8.5	6.9	6.8	7.3	7.4	8.5
134	8.1	8.4	7.6	8.2	8.1	6.9	6.9	6.9	6.6	6.9	7.0	6.9	6.9	6.9	7.8	7.0	8.5	8.1	6.9	6.8	7.3	7.4	8.5
135	8.6	8.8	7.8	8.1	7.5	7.8	7.0	7.3	7.1	7.7	6.2	7.1	6.5	6.9	6.9	7.0	7.0	7.4	7.2	6.8	6.9	7.4	8.6
136	8.7	8.8	7.8	8.0	7.7	7.4	6.6	7.2	7.1	7.4	6.2	7.1	6.5	6.9	6.9	7.0	7.0	7.4	6.9	6.8	6.9	7.4	7.0
137	8.8	8.8	8.1	8.3	8.2	7.9	7.8	7.6	7.1	7.6	7.7	7.3	7.4	7.6	8.3	7.0	7.0	8.6	7.3	6.8	7.7	7.4	7.0
139	8.8	9.0	8.0	8.5	8.2	8.0	6.7	7.4	7.3	7.6	6.5	7.3	6.9	6.9	6.9	7.0	7.0	7.4	7.3	7.3	6.9	7.4	8.3
141	8.5	8.9	8.0	8.2	7.7	7.9	7.5	7.3	7.4	7.7	7.3	7.2	7.5	7.5	8.2	8.3	7.0	8.7	6.9	6.8	7.7	8.2	7.5
142	8.7	8.8	8.1	8.9	8.5	7.8	7.5	7.4	7.1	7.2	6.6	7.2	7.2	6.9	6.9	7.0	8.8	6.9	7.2	7.3	6.9	7.4	7.8
143	8.8	8.9	7.8	8.5	8.5	7.6	7.8	7.5	7.0	7.7	7.6	7.3	7.2	7.5	8.2	7.0	7.0	8.5	6.9	6.8	8.0	8.7	7.0
144	8.8	8.8	7.4	8.4	8.0	7.3	7.0	7.3	6.6	7.3	6.6	6.9	6.5	6.9	6.9	7.0	7.0	7.6	6.9	6.8	6.9	7.4	8.2
145	8.5	8.9	8.0	8.8	8.4	8.1	7.6	7.5	7.4	7.6	6.5	7.2	7.2	6.9	6.9	7.0	8.9	6.9	7.4	7.3	6.9	7.4	8.1
146	8.5	8.9	7.6	8.2	7.8	7.5	6.5	7.3	7.1	7.3	6.2	7.2	6.2	6.9	6.9	7.0	7.0	7.5	7.1	6.8	6.9	7.4	7.0
147	8.8	9.0	8.1	8.7	8.3	7.8	7.6	7.3	7.3	7.5	6.5	7.2	7.1	6.9	6.9	7.0	7.0	6.9	7.3	7.2	6.9	7.4	8.5
303	7.2	7.3	7.3	7.4	7.5	6.9	7.1	7.3	6.6	7.5	7.0	7.2	6.9	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	7.7
309	7.2	6.9	6.9	7.1	7.3	7.2	7.1	7.1	6.6	7.3	7.0	6.9	6.9	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	8.3
314	8.8	7.9	7.4	7.7	8.0	7.3	7.4	7.3	6.6	7.6	7.2	6.9	7.2	6.9	7.9	7.0	8.7	8.5	6.9	6.8	6.9	7.4	7.8
317	8.2	8.7	7.6	8.0	7.3	7.2	6.4	7.2	6.6	6.9	6.2	7.1	6.2	6.9	6.9	8.6	7.0	6.9	6.9	6.8	6.9	7.4	7.0
319	8.5	6.9	8.1	7.1	8.2	7.9	7.9	7.3	7.2	7.2	7.4	7.1	7.2	6.9	6.9	7.0	7.0	8.5	6.9	6.8	6.9	7.4	8.7
321	8.5	7.4	7.9	8.5	8.2	7.9	7.6	7.3	7.0	7.1	7.3	7.2	7.4	6.9	6.9	7.0	7.0	8.0	6.9	6.8	6.9	7.4	8.7
322	8.5	7.6	7.6	8.6	8.2	8.0	7.7	7.3	7.2	7.2	7.4	7.2	7.2	6.9	6.9	7.0	7.0	8.5	6.9	6.8	6.9	7.4	8.8
325	8.5	7.6	8.1	8.1	7.4	8.0	7.6	7.3	7.1	7.1	7.1	7.2	7.3	6.9	6.9	7.0	7.0	7.9	6.9	6.8	6.9	7.4	8.8
326	8.5	7.4	7.5	8.0	7.9	7.9	7.7	7.3	6.9	6.9	7.2	7.2	7.4	6.9	6.9	7.0	7.0	8.2	6.9	6.8	6.9	7.4	8.8
340	7.9	8.0	7.3	8.6	7.4	7.1	6.8	7.1	6.6	7.3	6.8	6.9	6.6	6.9	6.9	7.0	7.0	6.9	6.9	6.8	6.9	7.4	7.6
353	7.2	8.2	7.8	8.5	8.1	7.3	7.2	7.2	7.1	7.7	7.4	7.2	7.4	6.9	7.9	7.0	7.0	8.5	6.9	6.8	6.9	7.7	7.0
356	8.7	7.2	7.8	8.1	8.2	7.1	7.5	7.3	6.6	7.1	7.3	6.9	7.4	6.9	6.9	7.0	8.7	8.5	6.9	6.8	6.9	7.4	8.8
361	8.3	8.0	8.1	8.1	8.2	7.7	7.7	7.3	7.1	7.2	7.4	7.2	7.2	6.9	6.9	7.0	7.0	8.1	6.9	6.8	6.9	7.4	8.8
362	8.2	7.1	7.1	7.7	7.5	6.9	7.2	6.9	7.0	7.1	7.0	6.9	6.9	6.9	6.9	7.0	7.0	8.2	6.9	6.8	6.9	7.4	8.5
Number positive	63	65	67	64	67	58	51	60	52	52	49	43	52	11	16	7	11	51	16	12	13	8	41

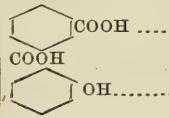
NOTE.—All cultures fermented pyruvic acid and none fermented oxalic and glycolic acids.

[1] Reactions were not determined on account of high color of the medium caused by bacterial growth.

The table shows that only a few cultures were able to ferment mucic, tartaric, and glyceric acid, in which there is a secondary alcohol radical connecting a carboxyl with another alcohol radical, as in mucic $COOH(CHOH)_4COOH$, tartaric $COOH(CHOH)_2COOH$, and glyceric $CH_2OH(CHOH)COOH$. It seems to be somewhat easier for this group of bacteria to obtain carbon from glyceric acid when a primary alcohol radical (CH_2OH) replaced a secondary (CHOH). Only 7 cultures were able to ferment tartaric acid, while none of the 68 cultures were able to utilize glycolic acid. Tartaric acid has a structural formula $\begin{array}{l} CHOH\ COOH \\ | \\ CHOH\ COOH \end{array}$ where an alcohol radical is linked to a carboxyl and another alcohol, while in glycolic $\begin{array}{l} CH_2OH \\ | \\ COOH \end{array}$ an alcohol radical is merely linked to a carboxyl. This difference in manner in which the alcohol radical is linked to the carboxyl may make it possible for some bacteria to ferment tartaric acid. In malonic acid $CH_2 \begin{array}{l} /COOH \\ \backslash COOH \end{array}$ two carboxyls are linked by a methyl group and it was found that 11 of the 68 cultures were able to obtain carbon from this source, while none of them were able to ferment oxalic acid $\begin{array}{l} COOH \\ | \\ COOH \end{array}$ when 2 carboxyl groups are joined directly. In this case it seems that the presence of the methyl group connecting the carboxyl group makes it possible for a few cultures to obtain carbon, probably from the methyl radical. Our results indicate that carbon is not obtained from the carboxyl group, since none of the cultures were able to utilize oxalic acid. This, however, may be due to the poisonous character of the acid. Whether this nonfermentability of the exalate is due to the configuration of the molecule or to the poisonous character of the compound, it is interesting to note that the work of Doryland (5) confirms this result as he was unable to obtain fermentation of oxalate when used as the only source of carbon in a synthetic medium in which 225 different bacteria were studied.

A large number of the cultures could utilize carbon from the sodium salt of formic acid. It is possible to consider the structure of this acid $HO-C \begin{array}{l} /\!\!/ O \\ \backslash H \end{array}$ and it seems evident that the carbon can be obtained from the aldehyd radical. If the structure is taken as H–COOH the organism would have to obtain carbon from a carboxyl group, and if they are able to do this with formic acid they should be expected to ferment oxalic acid.

TABLE 11.—*Summary of the fermentation of the organic-acid salts.*

Acid.	Chemical structure.	Number of cultures fermenting.	Remarks.
Pyruvic	$CH_3CO\,COOH$	68	Ketone connecting a carboxyl and a methyl radical.
Citric	$\left\{\begin{matrix} CH_2-COOH \\ COH-COOH \\ CH_2-COOH \end{matrix}\right\}$	63	Secondary or tertiary alcohol radical linked to a carboxyl and to a methyl radical.
Malic	$\left\{\begin{matrix} CH-(OH)\,COOH \\ CH_2-COOH \end{matrix}\right\}$	65	
Lactic	$\left\{\begin{matrix} CH_3 \\ CHOH \\ COOH \end{matrix}\right\}$	67	
Succinic	$\left\{\begin{matrix} CH_2-COOH \\ CH_2-COOH \end{matrix}\right\}$	64	
Acetic	CH_3COOH	67	No alcohol radical. Methyl linked to a carboxyl radical.
Propionic	CH_3CH_2COOH	58	
Butyric	$CH_3CH_2CH_2COOH$	51	
Valeric	$CH_3CH_2CH_2CH_2COOH$	49	
Caproic	$CH_3CH_2CH_2CH_2CH_2COOH$	52	
Mucic	COOH (CHOH) (CHOH) (CHOH) (CHOH) COOH.	11	Alcohol radical linked to a carboxyl and to another alcohol radical.
Glyceric	CH_2OH (CHOH) COOH	16	
Tartaric	COOH (CHOH) (CHOH) COOH	7	
Oxalic	$\left\{\begin{matrix} COOH \\ COOH \end{matrix}\right\}$	0	Two carboxyls linked together.
Malonic	$CH_2 < \begin{matrix} COOH \\ COOH \end{matrix}$	11	Two carboxyls linked with methyl radical.
Glycolic	$\left\{\begin{matrix} CH_2OH \\ COOH \end{matrix}\right\}$	0	Primary alcohol linked with a carboxyl.
Formic	$H-C < \begin{matrix} O \\ OH \end{matrix}$	51	Aldehyd radical linked to hydroxyl.
Benzoic		16	Benzol ring.
Salicylic		12	

Total number of cultures, 68.

Some of the bacteria were able to obtain their carbon from benzoic and salicylic acids, in which case it was apparently necessary for the bacteria to split the benzol ring. If they could obtain their carbon without splitting the benzol ring they would have to take it from the COOH group, and if it was possible in this case, it would be expected that they could also obtain carbon from the COOH group of oxalic acid. The sodium salt of benzoic acid was fermented by more cultures than that of salicylic acid, as is shown by the fact that 16 cultures fermented benzoic and only 12 salicylic. The stronger antiseptic property of salicylic acid, which possibly is due to the presence of the hydroxyl group, may make it difficult for some of the bacteria to grow in the presence of the acid salts.

The results of the study of the fermentation of the organic-acid salts indicate that some of the bacteria could obtain their carbon from the methyl, alcohol, or aldehyd (as in formic acid) radical of the salts of organic acids but not from the carboxyl group. Carbon was most easily obtained from the methyl group, as is shown from Table 11, where it is seen that most of the cultures were able to obtain their carbon from acids which had no alcohol radical, such as succinic or acetic. They were able to obtain it to about the same extent from citric, malic, and lactic acids, which contained both the methyl and alcohol radicals. In this case it is believed that the methyl radical supplies the carbon, since acids containing merely the alcohol radicals were not readily fermented. Only a small number of the cultures utilized the carbon from the alcohol radical where it was linked with a carboxyl and another alcohol radical, as in mucic, tartaric, and glyceric acid. The carbon did not seem to be utilized from an alcohol radical linked only to a carboxyl radical, as in glycolic acid. Pyruvic acid was easily fermented by all the cultures, and in this case the carbon may come from either the methyl or ketone radical. A. Fischer mentions in his book "The Structure and Functions of Bacteria," published in 1897, that bacteria are able to utilize carbon from the methyl radical more readily than from the alcohol radicals and they are unable to utilize the carbon from the carboxyl radical, as in oxalic acid. Our results confirm his opinion in the matter.

When the salts of organic acids were fermented an alkaline reaction was produced in most cases, the exceptions being butyric, valeric, and caproic acids. In the case of these acids the fermentation may proceed in one of two ways: Either the methyl radicals may be oxidized until a carbonate is produced and the medium becomes alkaline, or the acid may be split into other acids containing fewer carbon atoms. For example butyric may be oxidized as follows:

$$\underset{\text{butyric}}{CH_3\,CH_2\,CH_2\,COOH} + O_2 = \underset{\text{acetic}}{2\,CH_3\,COOH}$$

$$\underset{\text{butyric}}{CH_3\,CH_2\,CH_2\,COOH} + O_2 = \underset{\text{formic}}{HCOOH} + \underset{\text{propionic}}{CH_3\,CH_2\,COOH}$$

The oxidation of butyric acid to other acids may account for the increased hydrogen-ion concentration produced by certain alkali bacteria, since under ordinary conditions this concentration is lowered by the production of carbonates. Both these forms of fermentation may take place at the same time, but in the great majority of cases one or the other predominated, as is shown in Table 10. While many of the cultures produced an acid reaction in n-butyric and n-valeric acids, all those which fermented isobutyric, α or β oxybutyric, and isovaleric acids produced an alkaline reaction.

In order to show whether the alkaline reaction was due to the production of carbonates or bicarbonates, or both, Table 12 has been prepared, using the organic acids which were utilized as test substances in this investigation. Here again attention is called to the fact that the essential process in the production of an alkaline reaction is the replacement of the relatively strong organic acids by the relatively weak carbonic acid. The figures in the table are based on the complete oxidation to the carbonate or bicarbonate of 100 c. c. of a 0.1 per cent solution of the acid. In the next to the last column of the table the tenth-normal equivalent is given in cubic centimeters for both the carbonate and bicarbonate. This table should be studied in connection with the plot in figure 1 which represents the change of any of the test acid salt media from the initial P_H 6.9. The resulting hydrogen-ion concentration obtained when known amounts of tenth-normal $NaHCO_3$ were added to the medium above is represented by one curve. The other curve was obtained similarly by plotting the resulting hydrogen-ion concentration when known amounts of tenth-normal Na_2CO_3 were added to the same synthetic medium. It will be noted that the large quantity of alkali generated by some of the fermentations could not possibly be due to the complete oxidation of the acid to bicarbonate. Let us take, for example, propionic acid; on complete oxidation this acid yields an equivalent of 1.3 cubic centimeters of tenth-normal alkali. From the curve it is seen that 1.3 cubic centimeters of tenth-normal alkali gives a hydrogen-ion concentration of P_H 7.9 while the average hydrogen-ion concentration of the alkali group of bacteria which fermented propionic acid was P_H 7.4.

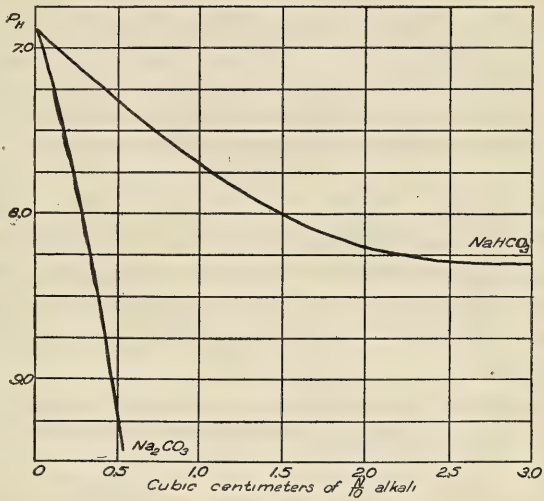


FIG. 1.—Curve showing effect of addition of bicarbonate and sodium carbonate on the reaction of the sodium-ammonium-phosphate medium.

From this it is evident that the entire amount of alkali produced from this organic-acid salt might be accounted for by the production of sodium bicarbonate. On the contrary, if we examine the figures for glyceric acid it will be found that this acid on complete oxidation yields an equivalent of 0.94 cubic centimeters tenth-normal alkali, which corre-

sponds on the plot to a hydrogen-ion concentration of P_H 7.65. The average hydrogen-ion of the cultures which fermented this acid was P_H 8.1; therefore the alkali produced by the fermentation of this organic-acid salt can not be due to the formation of sodium bicarbonate alone but must be due to sodium carbonate, or a combination of the two. In the 14 acids calculated and shown in Table 12 by similar manipulation of the plot, it was found that 6 of the acid salts, namely, citric, malic, succinic, glyceric, tartaric, and malonic produced alkali enough to account for the production of sodium carbonate alone, or the carbonate and bicarbonate together. The remaining acid salts can furnish alkali enough upon complete oxidation to account for the entire alkalinity either through the formation of sodium bicarbonate alone or a combination of the two. These plots do not show exactly the conditions found in the cultures when there is a replacement of a strong acid radical by the weak carbonic acid. Although these plots show only the effect of the addition of carbonates, they nevertheless clearly indicate the tendency of both the carbonate and bicarbonate to decrease the P_H value of the medium. They further show the relatively weak effect of bicarbonate when the medium is at a P_H included in the zone where the carbonic-bicarbonate equilibrium is obtained, and indicate very nearly the quantitative effect of the replacement mentioned above provided the acid replaced has a dissociation constant much larger than that of carbonic acid. This last condition does in fact apply to all the acids studied.

TABLE 12.—*Theoretical carbonate production from organic-acid salts, together with the average P_H value produced by the alkali-forming bacteria.*

Acid.	Na_2CO_3 obtained by complete oxidation of 0.01 gram of acid.	$NaHCO_3$ obtained by complete oxidation of 0.01 gram of acid.	Equivalent in N/10 alkali.	Average hydrogen-ion concentration.
	Gram.	*Gram.*	*C. c.*	P_H.
Citric	0.008275	0.01311	1.562	8.53
Malic	.007905	.01252	1.490	8.56
Lactic	.005887	.009333	1.110	7.72
Succinic	.008974	.01422	1.693	8.32
Acetic	.008822	.01399	1.665	8.00
Proprionic	.007158	.01134	1.351	7.42
Butyric	.006019	.09541	1.136	7.27
Mucic	.005165	.007997	.9520	7.53
Glyceric	.004996	.007921	.9429	8.10
Tartaric	.007062	.01119	1.333	8.33
Malonic	.01020	.01615	1.923	8.66
Formic	.0152	.01826	2.169	8.20
Benzoic	.004341	.006882	.8191	7.15
Salicylic	.003838	.06084	.7241	7.25

When hippuric and uric acids and urea were used no other source of nitrogen was supplied; therefore the organisms had to obtain both their necessary carbon and nitrogen requirements from these com-

pounds. The urea was sterilized through a Berkefeld filter, so there was no ammonium carbonate present as would have been the case if the ordinary method of steam sterilization had been employed. Ammonia was an end product from all three of these test substances, and with urea the only alkali end product possible. Reference to Table 10 shows that 13 of the cultures fermented hippuric acid, 8 uric acid, and 41 urea. In addition to the 68 cultures of alkali-forming bacteria isolated from dairy products, the fermentation of the organic-acid salts was tried with 55 known cultures, namely, 37 strains of dysentery, 6 of proteus, 6 of typhoid, 3 of paratyphoid, and 1 each of *B. abortus*, *B. bronchisepticus*, *B. fæcalis alkaligenes*, and *B. enteriditis*. The results of the fermentation of the citric and lactic salts and litmus-milk reaction are given in Table 13. It is evident from the results that all the cultures fermented the citrate and a large number of them the lactate. Many of the cultures gave characteristic milk reaction of the alkali-forming group of bacteria.

TABLE 13.—*Fermentation of the sodium salt of citric and lactic acid together with the milk reactions of known cultures.*

Culture.	Litmus-milk reaction, 7 days at 30° C.	P_H value, 3 days at 37° C.		Culture.	Litmus-milk reaction, 7 days at 30° C.	P_H value, 3 days at 37° C.	
		Citric.	Lactic.			Citric.	Lactic.
Control		6.8	7.2	Dysentery—Continued.			
Proteus:				8	No change	7.4	7.3
ACL	Alkaline	8.4	6.9	9	Slight acid	7.4	7.1
ACN	do	8.8	8.6	10	No change	7.4	7.4
ACU	do	8.3	7.2	11	do	7.4	7.1
ACV	do	8.3	7.0	12	do	7.4	7.3
ADE	do	8.4	7.3	13	Coagulated, acid.	7.4	7.4
ADG	do	8.3	7.0	14	Slight acid	7.4	7.3
Typhoid:				15	do	7.4	7.4
607	Coagulated, acid.	7.5	7.3	16	Alkaline	7.4	7.5
608	No change	7.4	7.3	17	No change	7.4	7.4
Rowd	Alkaline	8.4	7.5	18	do	7.4	7.1
M. T. S.	Slight acid	7.3	7.3	20	do	7.4	7.3
Hop	Coagulated, acid.	7.4	7.3	21	do	7.4	7.2
Hop 22	do	7.5	7.0	22	Coagulated, acd.	7.4	7.8
Paratyphoid:				23	Slight alkaline	8.6	Lost.
16	No change	7.4	7.0	24	Slight acid	7.4	7.0
22	Alkaline	8.5	7.3	25	do	7.4	7.0
323	do	8.5	7.7	26	do	7.4	7.0
B. enteriditis	do	8.5	7.3	27	No change	7.4	7.4
B. abortus	do	8.4	7.5	28	do	7.4	7.3
B. bronchisepticus.	do	7.3	7.3	29	do	7.4	7.3
Dysentery:				30	do	7.4	7.4
1	No change	7.4	7.3	31	do	7.4	7.3
2	do	7.4	7.1	32	Slight acid	7.4	7.1
3	Slight acid	7.4	7.3	33	No change	7.4	7.5
4	No change	7.4	7.3	34	do	7.4	7.3
5	Slight acid	7.4	7.4	35	do	7.4	7.3
6	do	7.4	7.4	36	do	7.4	7.3
7	No change	7.4	7.0	37	Slight acid	7.4	7.0
				38	No change	7.4	7.4

The salts of organic acids not only serve as a source of carbon for the alkali-forming bacteria and, therefore, are valuable test substances, but their use need not be limited to the bacteria of this group. In fact, it seems probable that they may have an extensive application in the study of other groups of bacteria.

REDUCTION OF NITRATES AND NITRITES.

In view of the fact that all the organisms of the alkali-forming group of bacteria could utilize nitrogen from nitrates, it is certain there must be a reducing action. It is of interest, therefore, to point out the action of these bacteria in reducing nitrates to nitrites, as is shown by the ordinary tests for reduction generally used in bacteriological work. The reduction of nitrate to nitrite was first tried in the ordinary nitrate broth, which consisted of 0.1 per cent peptone and 0.02 per cent potassium nitrate. Cultures were incubated in the broth for seven days at 30° C., then tested for the presence of nitrite. The results of these tests are shown in Table 14. It will be seen that according to this test only seven cultures reduced nitrate to nitrite. Reduction of nitrate was then tested by using a medium in which beef extract was the source of nitrogen. In one case 0.2 per cent extract was used with 0.02 per cent nitrate, and in another case 0.1 per cent extract with the same amount of nitrate. The results in the table show that after 24 hours in the 0.2 per cent beef extract 11 cultures reduced the nitrates, while in the 0.1 per cent beef extract 18 cultures gave a nitrite test. After seven days' incubation 47 cultures reduced nitrate in 0.2 per cent beef extract and 40 cultures in 0.1 per cent beef extract.

TABLE 14.—*Reduction of nitrates and nitrites in simple and complex media.*

Culture No.	0.1 per cent peptone, 0.02 per cent potassium nitrate.	0.2 per cent beef extract, 0.02 per cent potassium nitrate.		0.1 per cent beef extract, 0.02 per cent potassium nitrate.		Sodium nitrate, 0.2 per cent; sodium-lactate, 0.25 per cent; sodium-dibasic phosphate, 0.1 per cent.		Sodium nitrite, 0.2 per cent: sodium lactate, 0.25 per cent; sodium-dibasic phosphate, 0.1 per cent.	
	Nitrite test, 7 days.	Nitrite test, 24 hours.	Nitrite test, 7 days.	Nitrite test, 24 hours.	Nitrite test, 7 days.	Nitrite test, 14 days.	Change in titration.	Ammonia test, 14 days.	Change in titration.
Control	—	—	—	—	—	—	—0.05	—	—0.10
10	—	—	+	—	—	+	— .61	—	—0.72
12	—	—	+	—	—	+	— .93	—	— .84
31	—	—	—	—	—	—	— .15	—	— .59
49	—	—	+	—	—	+	— .93	—	— .76
59	—	—	—	—	—	+	—1.20	—	—1.28
60	—	—	+	—	+	+	—1.15	—	—1.08
61	—	—	—	—	—	+	—1.05	—	—1.21
62	—	—	—	—	—	+	—1.18	—	—1.31
66	—	—	+	+	+	+	—1.21	—	—1.16
72	—	—	+	—	+	+	— .58	—	— .66
73	+	+	+	+	+	+	0 [1]	—	— .42
101	—	—	+	—	+	+	— .95	—	— .99
102	—	—	—	—	—	+	— .95	—	— .95
103	—	—	—	—	+	0 [2]	0	—	0
104	—	—	+	+	+	+	— .84	—	— .87
105	—	—	+	—	+	+	— .92	—	—1.26
106	—	—	+	—	—	+	—1.12	—	— .86
107	—	—	—	—	—	+	— .82	—	— .49
108	—	—	+	+	+	+	— .89	—	— .90
111	—	—	+	—	+	+	—1.27	—	—1.05

[1] "0" means no change in titration. [2] "0" under nitrite test means no growth of culture.

TABLE 14.—*Reduction of nitrates and nitrites in simple and complex media*—Contd.

Culture No.	0.1 per cent peptone, 0.02 per cent potassium nitrate.	0.2 per cent beef extract, 0.02 per cent potassium nitrate.		0.1 per cent beef extract, 0.02 per cent potassium nitrate.		Sudium nitrate, 0.2 per cent; sodium-lactate, 0.25 per cent; sodium-dibasic phosphate, 0.1 per cent.		Sodium nitrite, 0.2 per cent; sodium lactate, 0.25 per cent; sodium-dibasic phosphate, 0.1 per cent.	
	Nitrite test, 7 days.	Nitrite test, 24 hours.	Nitrite test, 7 days.	Nitrite test, 24 hours.	Nitrite test, 7 days.	Nitrite test, 14 days.	Change in titration.	Ammonia test, 14 days.	Change in titration.
112	−	−	+	−	+	+	− .95	−	− .57
113	−	−	+	−	−	+	− .63	−	− .40
114	−	−	+	−	+	+	− .92	−	− .81
116	−	−	+	+	+	−	− .79	−	− .99
117	−	−	+	−	+	+	− .97	−	− .77
118	−	−	+	−	+	+	−1.07	−	−1.20
119	−	−	−	−	+	−	− .93	−	− .86
120	−	−	+	−	+	+	− .85	−	− .35
121	+	+	+	+	+	+	− .11	−	− .66
122	−	−	−	−	−	−	− .07	−	−1.40
123	−	−	+	+	−	+	− .97	−	− .63
124	−	−	+	−	+	+	− .87	−	− .99
125	−	−	+	+	+	+	−1 03	−	− .96
126	−	−	+	−	+	+	−1.01	−	− .84
128	−	−	+	−	+	+	− .85	−	− .85
130	−	−	−	−	−	+	−1.09	−	−1.12
131	−	−	−	−	−	−	− .97	−	− .68
132	−	−	−	−	−	+	− .93	−	− .91
133	+	+	+	+	+	+	− .05	−	− .62
134	+	−	+	+	+	+	− .91	−	− .51
135	−	−	−	−	−	+	−1.02	−	− .87
136	−	−	−	−	−	+	− .97	−	− .88
137	−	−	−	−	−	+	− .89	−	− .63
138	−	−	−	−	−	+	−1.15	−	−1.01
139	−	−	−	−	−	+	−1.10	−	−1.33
141	−	−	+	−	+	+	− .95	−	− .19
142	−	−	+	−	+	+	−1.08	−	−1.45
143	−	−	+	−	−	+	− .76	−	− .72
144	−	−	+	−	+	+	−1.07	−	−1.01
145	−	−	+	−	+	+	− .97	−	−1.34
146	−	−	+	−	+	+	−1.05	−	−1.00
147	−	−	−	−	−	0	0	−	−1.51
303	−	−	−	−	−	0	0	−	0
309	−	+	+	−	+	0	0	−	0
314	−	−	+	+	+	+	−1.19	−	−1.52
317	−	−	−	−	−	0	0	−	− .51
319	−	−	+	−	+	+	− .88	−	− .26
321	−	+	+	+	+	+	− .75	−	− .72
322	+	+	+	+	+	+	− .94	−	− .97
325	−	+	+	+	+	+	− .90	−	− .48
326	−	+	+	+	+	+	−1.00	−	− .51
340	−	+	+	−	+	0	0	−	0
353	+	+	+	+	+	+	− .41	−	− .23
354	−	−	−	−	−	+	− .84	−	− .61
356	+	+	+	+	+	+	−1.10	−	− .62
361	−	−	+	−	+	+	− .90	−	− .18
362	−	−	+	+	+	+	− .18	−	− .43

It is interesting to compare the number of positive nitrite tests in the peptone nitrate broth, where only seven cultures gave a positive nitrite test after seven days, with the 0.2 per cent beef-extract nitrate broth where 47 out of a total of 68 cultures showed a nitrite test after seven days. This small number of reductions

of nitrate to nitrite in peptone broth was probably due to the fact, which has been previously explained, that the organisms of the group did not develop well in peptone solution. While they could use it as a source of nitrogen with a suitable source of carbon, it was a poor source of nitrogen when used alone. With beef extract a source of carbon was probably supplied for the alkali-forming bacteria from the salts of the organic acid present in the extract; consequently these bacteria could grow better, and as a result there was a larger number of cultures which could reduce the nitrate to nitrite.

It has been seen, however, that these bacteria could utilize nitrogen from nitrate; consequently it should be expected that all the cultures should show a reduction and a positive nitrite test. Tests were made, therefore, in a medium containing 0.2 per cent of sodium nitrate, 0.25 per cent sodium lactate, and 0.1 per cent sodium-dibasic phosphate in distilled water. This medium was inoculated and incubated at 30° C. for 14 days and then tested for the presence of nitrite. Table 14 shows that 57 cultures gave a positive nitrite test. Seven did not grow in the experiment, although at other times they grew in the same medium. The remaining four cultures did not show a positive nitrite test. In order to show that there was a growth in all cases except the seven mentioned, titrations were made to determine the production of alkaline carbonates due to the oxidation of the sodium lactate. It will be seen from the table that all the cultures except those which did not show any growth produced an alkaline reaction. Even the five cultures which showed negative nitrite tests produced an alkaline reaction, showing that the nitrogen for growth must have been obtained from sodium nitrate; consequently there must have been a reduction. The probable reason why there was growth without a nitrite reaction is because nitrites may be utilized by this group of alkali-forming bacteria as well as nitrates. This is shown in Table 14 through the alkaline change in reaction in the medium composed of 0.2 per cent sodium nitrite, 0.25 per cent sodium lactate, and 0.1 per cent dibasic-sodium phosphate and distilled water.

It will be seen from the results that all but 5 cultures produced an alkaline change, showing the ability of the organisms to utilize sodium nitrite as a source of nitrogen and consequently reduce it. The five cultures that failed to show the nitrite test in the sodium-nitrate medium all produced an alkaline change in the sodium-nitrite-lactate medium. It is probable that these organisms failed to show a positive nitrite test because the nitrite was used up as soon as formed from the nitrate. Since these alkali-forming bacteria could reduce nitrite, it was natural to expect that it might be possible to determine the reaction by means of the determination of ammonia as shown by

Nessler's reagent; consequently all the cultures in sodium-nitrite-lactate medium were tested for the presence of ammonia. The test, however, was found to be negative and since it was known that these bacteria could utilize ammonia as a source of nitrogen the results indicate that as the nitrite was reduced to ammonia the latter was immediately used up.

The results showing the reduction of nitrate and nitrite by the alkali-forming group of bacteria are of particular interest, since they point out the difficulty of obtaining accurate tests for these reductions without a thorough understanding of the physiology of the bacteria.

ARBITRARY GROUPING OF THE ALKALI-FORMING BACTERIA FROM MILK.

An attempt has been made to arrange into groups the 68 alkali-forming bacteria used in this study in order to show the possibility and emphasize the use of the organic-acid salts, carbohydrates, and alcohols as test substances when used as the only source of carbon in a synthetic medium. In the chart, figure 2, it may be seen that the cultures have been divided first according to their morphology into cocci and bacilli, then further subdivided on the basis of their fermentation of dextrose. After the division of the cultures into positive and negative dextrose, they are again divided into subgroups according to their ability to ferment mucic, tartaric, malonic, or glyceric acid salt. In this grouping, in order to differentiate further and bring out the main points of difference in the cultures, the following organic salts were used—formic, butyric, valeric, hippuric, uric, and urea. While these organic-acid salts were used to group the cultures, it often happened that other easily fermented organic-acid salts not mentioned had to be utilized to distinguish the different subgroup members further. Examples of such are the salts of malic, acetic, and citric acids.

For the convenience of those who may study alkali-forming organisms each subgroup has been given an arbitrary number. The fermentation of dextrose and the salts of the organic-acid salts mentioned were, for the purpose of this paper, considered primary characteristics in distinction to the secondary characteristics which are shown in the lower half of figure 2. It is of interest to observe that the alkali-forming bacteria studied in this work and grouped according to what are considered primary characteristics, also had secondary characteristics which correlated with the primary. Thus by referring to the chart it may be seen that all the fluorescent cultures fell into subgroup 4, all the gelatine liquefiers fell into subgroup 6, while all the cultures that fermented the alcohols, such as mannite and glycerin, fell into subgroup 9. The only cultures that showed gas in dextrose broth also were in subgroup 9. The pigment formers, which were also the cultures that fermented saccharose, fell into

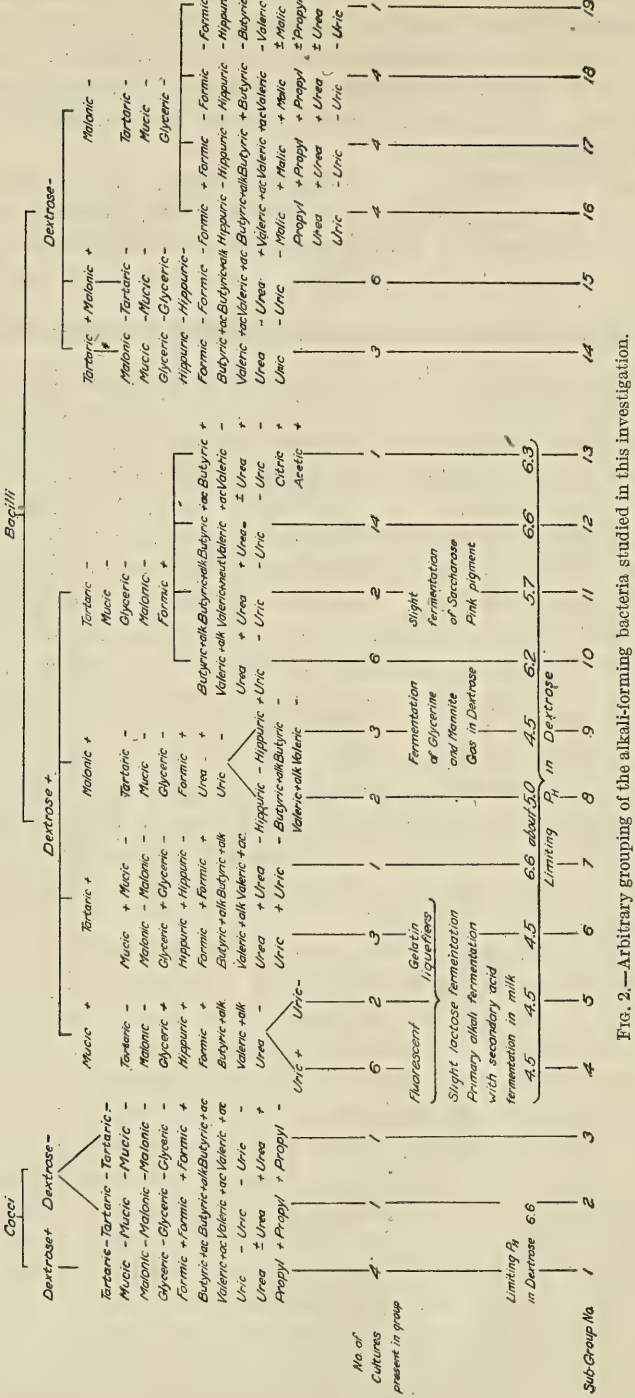


FIG. 2.—Arbitrary grouping of the alkali-forming bacteria studied in this investigation.

subgroup 11. Another noticeable secondary characteristic was the uniform limiting P_H value in dextrose medium A, the composition of which was given on page 13. Each subgroup of the dextrose fermenters utilized the carbohydrate to a practically constant limiting hydrogen-ion concentration, as is shown for example in subgroup 10, where all the 6 cultures fermented dextrose to P_H 6.2 after 7 days' incubation at 30° C. The reaction in milk was similar in subgroups 4, 5, and 6. In these 3 groups there was first a primary alkali fermentation which was followed by what was apparently a secondary acid fermentation, during a period of 30 days' incubation. The secondary characteristics of this group have been given in detail so as to emphasize further and show the possibility of the new method of grouping alkali-forming bacteria according to their ability to utilize carbon when supplied in a synthetic medium from organic-acid salts, carbohydrates, and alcohols. It was impossible to make this study cover all types of the alkali-forming bacteria, because the definition chosen for this group is so simple and yet so comprehensive that it must include a very large number of species of bacteria. Therefore, the scheme for grouping this particular collection of alkali-forming organism is not intended for a definite classification of all the alkali-forming group of bacteria. It should serve, however, as a possible basis for future work along this line and particularly to draw attention to the fact that the fermentation of organic-acid salts is a reliable and important means for classification, especially for organisms of this type occurring in soil.

SUMMARY AND CONCLUSIONS.

1. The alkali-forming bacteria may be defined as those bacteria which produced an alkaline reaction in milk without visible signs of peptonization. In litmus milk this reaction appeared sometimes within 48 hours, usually within 5 days, while occasionally a longer period was required. The alkaline reactions were caused primarily by the oxidation of the salts of citric acid to alkaline carbonates. Other organic-acid salts if present in milk may also be similarly fermented. Ammonia played little or no part in causing the alkaline reaction during the first 7 days of incubation, but at later periods a few cultures produced considerable ammonia. Several cultures showed a primary alkaline fermentation which was followed by what was probably a secondary acid fermentation.

2. The alkali-forming bacteria studied were isolated principally from milk, a few being obtained from ice cream. These organisms were found in large numbers in numerous samples of soil and also water. They were present in large numbers on the hands of farm laborers, and in unsterilized milk utensils. While not present in the udders of cows, the alkali-forming bacteria were present in relatively small numbers in cow feces. It seems evident that the

organisms of this group found in milk were principally soil bacteria introduced into milk largely from unsterilized utensils, with dust, or from the dirty hands of milkers. Cow feces may also play a small part in the contamination. In general, soil can not be considered the only source of these organisms, because there are many bacteria from other sources, which would be placed in this group on account of producing the characteristic milk reaction.

3. Cultures of the bacteria included both cocci and bacilli which grew best aerobically at temperatures ranging from 20° to 30° C. When heated in milk for 30 minutes, the thermal death point of these organisms ranged from 60° to 65.6° C. No spores were observed. Most of the cultures produced a slimy growth on agar, several showed fluorescence and a few showed pigment formation.

4. Sodium-ammonium phosphate was used as a source of nitrogen in the study of the alkali-forming bacteria. While the organisms could utilize nitrogen from numerous organic materials when suitable sources of carbon were supplied, either contained in them or supplied from other sources, it was found necessary in studying the fermentation of test substances to have a definite source of nitrogen free from carbon.

5. In studying the fermentation of test substances, nitrogen was supplied by sodium-ammonium phosphate, while the test substance furnished the carbon. The ordinary beef-extract broth was not found to be suitable for the determination of the fermentation of carbohydrates, because carbon was available either from the carbohydrate used or the organic-acid salts present in the beef-extract broth. It was possible, therefore, for a simultaneous acid (from the carbohydrate) and alkaline (from the organic-acid salts) fermentation to take place, in which case the final reaction would depend on the rate of the two fermentations. It was often found that in beef-extract broth the acid fermentation was entirely masked by the alkali fermentation. To overcome this as far as possible a synthetic medium was used which contained a single source of nitrogen and single but different source of carbon. Dextrose was the most easily fermented of the carbohydrates tested. Of the 68 cultures examined 44 fermented dextrose, 11 lactose, and 2 saccharose, while none fermented raffinose. Dextrose and galactose were fermented to about the same extent and many media showed a high hydrogen-ion concentration, while lactose and saccharose were fermented only slightly. In extract broth there was no evidence of a lactose fermentation—in fact, the reaction went alkaline—but in the synthetic medium a sight but distinct fermentation was observed.

6. The monoatomic alcohols ethyl, propyl, and amyl were more readily fermented than the polyatomic alcohols mannite and glycerin. The alcohols tested were the only source of carbon in the sodium-ammonium-phosphate medium.

7. Organic-acid salts were easily available as sources of carbon when used in the synthetic medium, and in most cases an alkaline reaction was produced, due to the formation of bicarbonates or carbonates. The exceptions were when the salts of n–butyric, n–valeric, or caproic acids were used. These acids may be split into other acids and if the fermentation is not carried far enough the reaction may become acid.

An attempt was made to determine from what radical or radicals the alkali-forming bacteria obtained their carbon. The results of the study indicate that it may come from the methyl, alcohol, or aldehyd (as in formic acid), but not from the carboxyl group (as in oxalic acid). Carbon was most easily obtained from the methyl group (as in succinic, acetic, etc.), and about as well from the methyl and alcohol group when attached (as in citric, malic, or lactic acid). Carbon was not easily available from the alcohol radical when it was linked to a carboxyl and another alcohol radical (as in mucic, tartaric, and glyceric acids). It was not available from an alcohol radical when linked to a carboxyl (as in glycolic acid). Apparently the benzol ring can be split by some bacteria, for a few of the cultures were able to obtain their carbon from the salts of benzoic and salicylic acids.

Some of the cultures were able to obtain both nitrogen and carbon from urea and also from uric and hippuric acids. Numerous known cultures, some of which give the characteristic alkaline milk reaction of the alkali-forming group, were capable of utilizing the salts of organic acids as a source of carbon when grown in a synthetic medium. Among these were cultures of proteus, typhoid, paratyphoid, and dysentery; also *B. abortus*, *B. bronchisepticus*, *B. fæcalis alkaligenes*, and *B. enteriditis*. It is believed therefore that the salts of organic acids may serve as valuable carbon-containing test substances for the further identification of bacteria.

8. The alkali-forming bacteria readily used the nitrates and nitrites as sources of nitrogen, but when tested for the reduction of nitrates and nitrites in the commonly used peptone medium very few showed any evidence of reduction. The ordinary method of testing the reduction of nitrates to nitrites is of no value when alkali-forming bacteria are being studied. This may be equally true of other groups of bacteria. Special media should be used, therefore, whenever possible.

9. An arbitrary division of the alkali-forming bacteria found in milk has been made. This classification was based primarily on the fermentation of dextrose and the salts of organic acids, and serves to show the value of the fermentation of the organic-acid salts for this purpose. Each subgroup has been given a number as a matter of convenience for those who may study these types of bacteria in

the future. No attempt has been made to group these cultures on the basis of the accepted principles of classification.

10. It is hoped that the results presented may give a clearer conception of certain types of alkaline fermentation. Probably many alkaline reactions presumed to be due to ammonia formation are in reality the result of the oxidation of organic-acid salts to alkaline carbonates. These alkaline fermentations, occurring as they may with acid fermentations, greatly complicate the fermentation of various test substances. This type of alkaline fermentation may explain many obscure results which occur in bacteriological studies. Furthermore, since organic acids are suitable sources of carbon for many bacteria, they may serve as an extensive set of test substances by means of which the physiological characteristics of bacteria may be further studied. The fermentation of organic-acid salts should be of particular value in the study of bacteria which fail to ferment the usual test substances, such as carbohydrates, alcohols, and starches.

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THE RICE MOTH.

By F. H. Chittenden,

Entomologist In Charge of Truck-Crop Insect Investigations.

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INTRODUCTION.

Among the insect enemies of stored products which have been observed recently in this country, a small whitish larva or caterpillar of the moth *Corcyra cephalonica* Stainton (Pl. I) has attracted attention by its injuries. It resembles somewhat the better-known fig moth (*Ephestia cautella* Walk.). It has not been noted as a pest of importance, and has been given no common or English name. As it is somewhat widely reported as destructive to stored rice it may be called the rice moth. Beginning with October, 1911, complaints of damage by this insect were received from a firm manufacturing chocolate in western Pennsylvania, and a year later from another manufacturing firm in the same State, but the species was not positively identified until 1916.

NATURE OF INJURY.

The first correspondent of the Bureau of Entomology who wrote of this insect stated that beans of cacao (*Theobroma cacao*) imported from the Tropics were subject to attack by the larva. Apparently it

laid its eggs in the beans, which are sometimes warehoused for several months, in the country from which they were shipped. During this period of storage additional generations of larvæ are hatched which destroy large quantities of the cacao beans or render them unfit for sale. The rice moths have been found most numerous in the older beans and also occur abundantly in cocoa nibs, in cocoa in powdered form, in refuse cocoa dust, and in ground cacao shells, so that they may be said to feed on any form of the cacao bean from the shells to the finished or edible article, cocoa or chocolate in powder, in cakes, and in confections, whether the substance is sweetened or unsweetened.

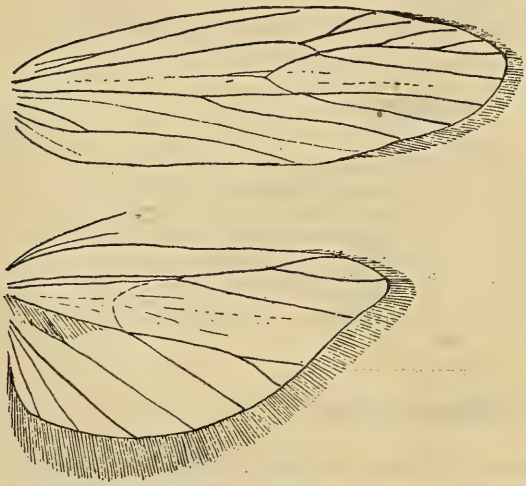


FIG. 1.—Diagram showing wing venation of the rice moth (*Corcyra cephalonica*). (After Durrant and Beveridge.)

Later moths and larvæ of this species were received in rice from different sources which will be mentioned hereafter.

This species works in much the same manner as do the fig moth (*Ephestia cautella* Walk.) and the Indian-meal moth (*Plodia interpunctella* Hbn.), forming a still stronger thread than do these related forms, and matting the infested material more closely. Indeed, this thread or webbing in the case of powdered cocoa becomes so dense that in close quarters the moths when emerging are scarcely able to make their exit. As a consequence of this and of the further fact that the food supply becomes too dry to be eaten, many of the larvæ perish. This is true not only under artificial conditions in the laboratory but has been noted in manufacturers' storerooms.

DESCRIPTIVE.

THE MOTH.

While, as previously stated, the rice moth resembles in certain respects some of our common moths which breed in stored cereals, dried fruits, and similar material, it does not belong to the same lepidopterous group, being a member of a different family, the Pyralidae, and subfamily, the Galleriinae, and closely related to a small group of moths which are best known as occurring in the combs of

honeybees and certain species of wasps. Indeed, it is most closely related to the lesser bee moth (*Achroia grisella* Fab.), a somewhat uncommon species in this country, but well known abroad.

Corcyra cephalonica is extremely variable in size, specimens which were first reared from material received from western Pennsylvania being quite small, while individuals from later generations are much larger, and in some cases show markings on the forewings more distinctly. A moth is shown in Plate I, A, with wings extended; the natural position at rest is shown in Plate I, B; and the wing venation is illustrated in text figure 1.

The following technical description is reprinted from Durrant and Beveridge:

Antennae whitish fuscous; basal joint with some darker fuscous scales. *Head* and *Thorax* very pale fuscous, sometimes whitish fuscous, or darker fuscous. Fore wings very pale fuscous, the veins more or less indicated by darker fuscous scaling, and with a tendency to suffusion over the whole wing, except along the dorsum which remains of the pale ground-color; in some specimens the darker markings are almost absent, in others there is a tendency to form two irregular transverse dark lines, one at the end of the cell, the other at about half the wing-length, with some dark shading toward the base; a more or less distinct dark spot occurs on the margin at the end of each vein; cilia pale fuscous, with some admixture of darker scales. *Exp. al.* 14–24 mm. Hind wings, ♂ fuscous; ♀ shining whitish fuscous; cilia with a slightly paler line at their base. *Abdomen* and *Legs* pale fuscous.

Synonymy.

Corcyra cephalonica Staint., Ragonot, Ent. Mo. Mag., v. 22, p. 22, 23, 1885.

Melissoblaptes (?) *cephalonica* Staint., Ent. Mo. Mag., v. 2, p. 172–173, 1866.

Melissoblaptes translineella Rag.-Hamps., Mém. Lep., p. 491, pl. 45, fig. 23; pl. 51, fig. 26, 1901.

Tineopsis theobromae Dyar, Ins. Inscit. Mens., v. 1, no. 5, p. 59, 1913.

THE EGG.

Pl. II.

The eggs have a pearly luster, are variable in shape, and have at one end usually a decided nipple, somewhat like that of certain fruits. The eggs are sufficiently large to be readily seen without the aid of a lens, and resemble somewhat those of the Mediterranean flour moth (*Ephestia kuehniella* Zell.). The exact dimensions have not been obtained.

THE LARVA.

Pl. III, A.

The larva when fully developed bears some resemblance to that of *Plodia interpunctella*. The sutures of the joints are somewhat more pronounced; the general color varies from white to a dirty, slightly bluish gray with occasional faint greenish tints. This dirty appearance of the larvæ is due to the dark material on which they feed and is especially evident in the immature stages. Larvæ which have fed on rice are more nearly white than those which develop from cacao preparations.

The head, without the mandibles, is truncate anteriorly and subtruncate posteriorly. The general color is rather dark honey-yellow, inclined to brown. The thoracic plate is pale honey-yellow, well divided at the suture and, while a little darker on the outer margin, is nearly uniform in color. The anal plate is very pale, scarcely darker than the joints. The three pairs of fore legs are rather long and prominent. The prolegs, with the anal legs, are also prominent but shorter. Observed under a strong lens the spiracles and piliferous tubercles are minute but distinct, and the pubescence, although sparse and of fine texture, is rather long, some hairs being nearly as long as the width of the body.

The average length when extended is about 13 mm. and the greatest width about 1.5 mm.

THE PUPA.

Pl. III, B, C.

In general appearance the pupa resembles that of other cereal-feeding moths. The general color is pale yellow. The form is robust, and the arrangement of the segments is well shown in Plate III, B and C, the latter illustrating the ventral arrangement of the legs and wing pads. These latter extend nearly to the antepenultimate abdominal segment. The eyes, in fresh specimens, show merely as circular areas but when nearing transformation they become black. The antennal sheathes slightly overlap on the posterior margin. The best characters appear on the dorsum, the short median parallel elevated longitudinal lines evidently being characteristic, as they are nearly black and quite distinctly marked. The spiracles are small but distinct. The anal segment bears at the apex four processes, the anterior ones being in the nature of short spines.

Naturally there is a difference in the proportions of the pupa of this species as in the adult, the length varying from 7.5 mm. to 9 mm.

When about to transform the larva prepares a cocoon by joining together, by means of silken threads, a mass of the material on which it is feeding, as shown in Plate IV, A. An exposed cocoon is illustrated in Plate IV, B.

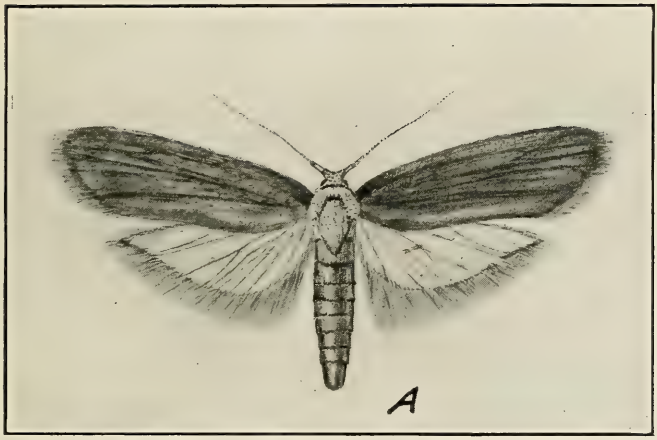
DISTRIBUTION.

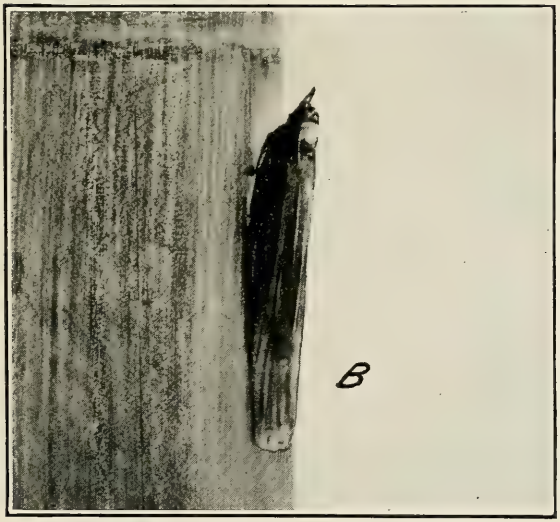
While *Corcyra cephalonica* is known to occur in portions of Europe, Asia, Africa, and southern and insular America, it is by no means truly cosmopolitan. Durrant and Beveridge (9)[1] record the Mediterranean region, India and Ceylon, the Cocos Keeling Islands, Christmas Island, the Kei Islands, western Sudan, Nyassaland, La Réunion, Pará, Brazil, and Cuba and Grenada, West Indies. Ragonot (7) records Italy, the Ionian Islands, and the Seychelles. To this list may be added Porto Rico, Mexico, Hawaii, and Pennsylvania.

FOOD HABITS.

According to the authors just mentioned the rice moth would appear to be of eastern origin, introduced into Europe and elsewhere by the rice trade, and this is undoubtedly true. They further state

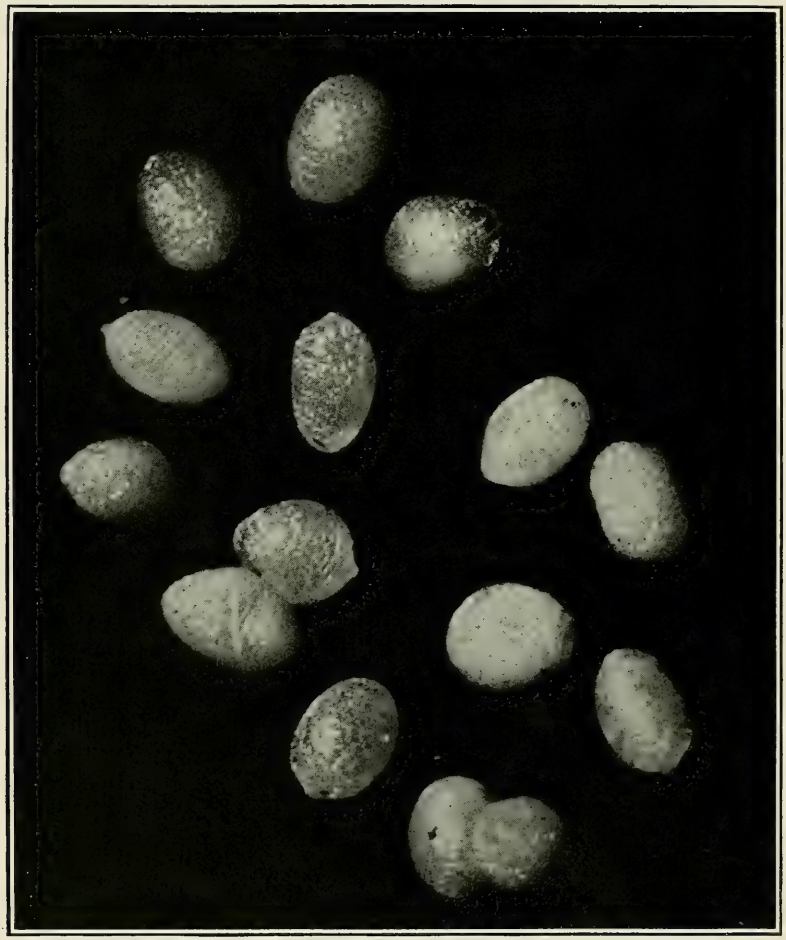
[1] Figures in parentheses refer to "Literature cited," p. 14.



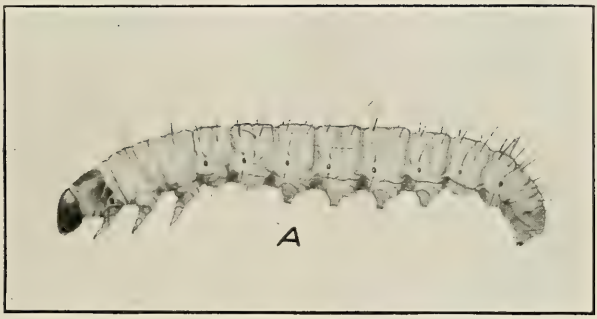


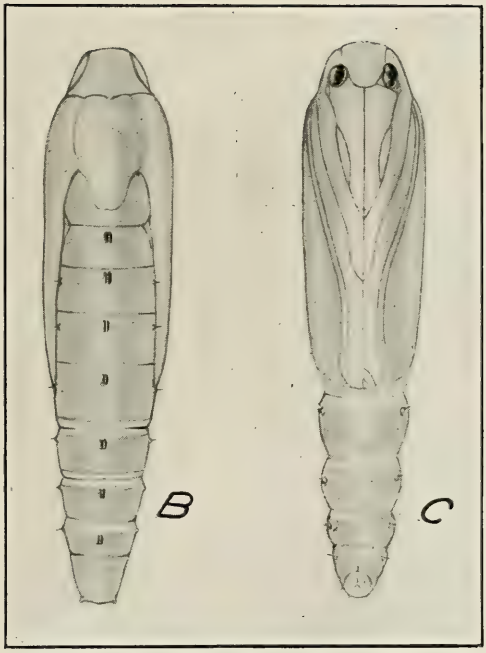
THE RICE MOTH (CORCYRA CEPHALONICA).

A, Mature moth; *B*, same in natural position at rest. Much enlarged.



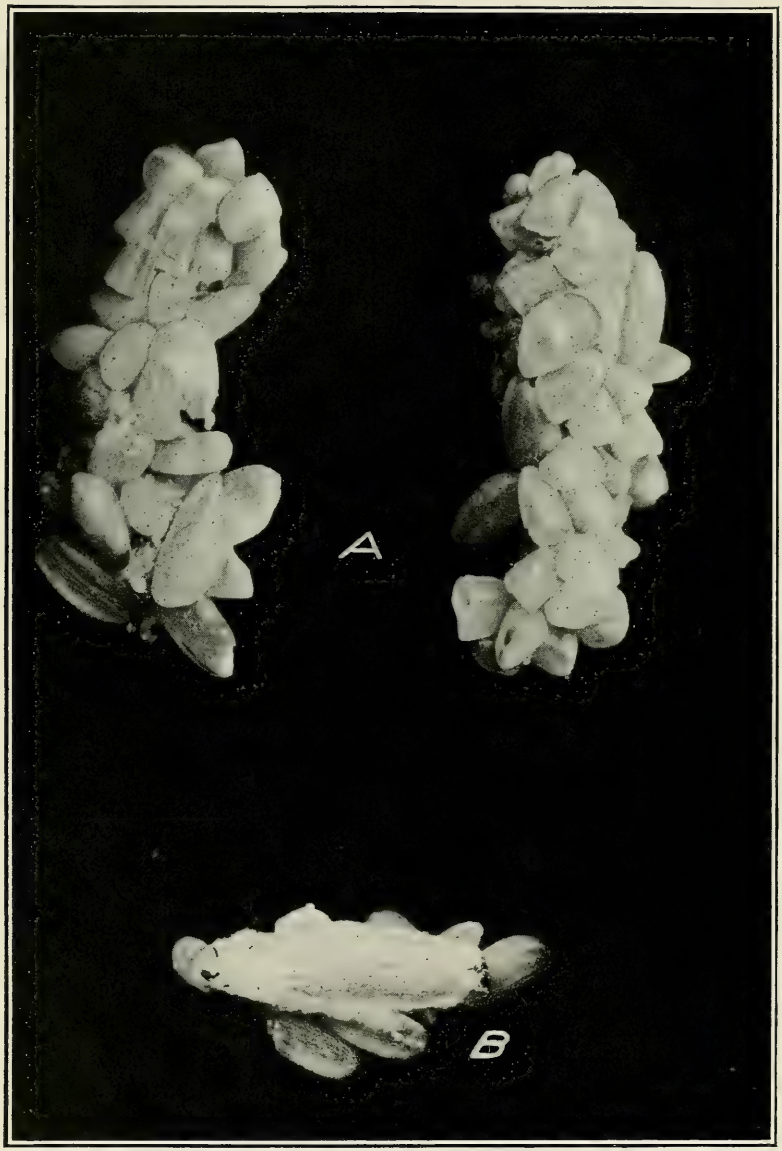
EGGS OF THE RICE MOTH. HIGHLY ENLARGED.





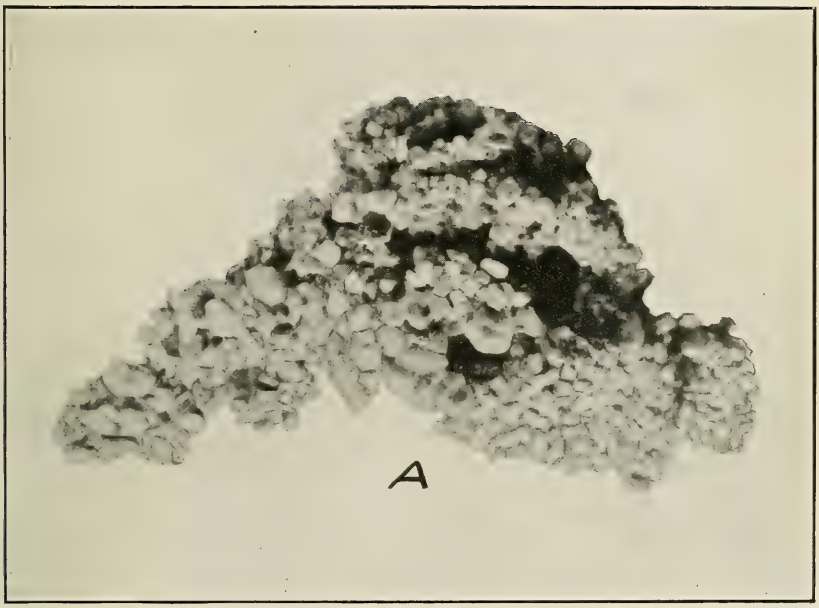
STAGES OF THE RICE MOTH.

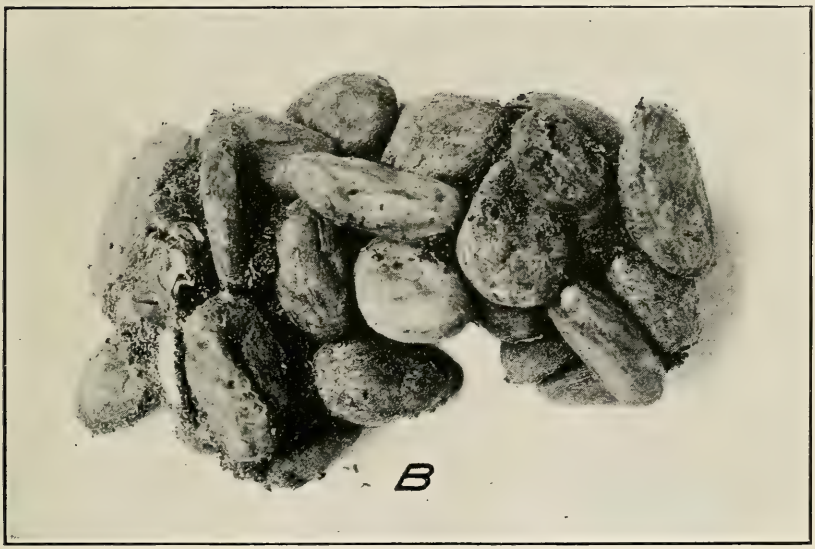
A, Larva; *B*, pupa, dorsal view; *C*, same, ventral view. Much enlarged.



COCOONS OF THE RICE MOTH.

A, Exterior, showing grains of rice; *B*, cocoon exposed by removal of rice grains. Enlarged.





WORK OF THE RICE MOTH.

A, Mass of rice closely matted together by larvæ; *B*, cacao beans similarly attacked.

that it was thought to be especially attached to currants, that it is imported into England with Rangoon rice, which seems to be its natural food, and that there is little doubt that anything that will suffice for the genus Ephestia will be equally nourishing to the present species. This insect was also obtained in tins of army biscuit, but no particulars are given as to its breeding habits beyond what has already been said. The larva has been observed in Paris in the grain of sesame (*Sesamum orientale*) from Sudan, West Africa.

Plate IV and Plate V, A, illustrate the manner in which the cocoons of the rice moth are made by the larva in confining the

FIG. 2.—Army biscuit showing holes eaten by larvæ of the rice moth and webbing by same. (After Durrant and Beveridge.)

grains of rice by means of silken threads. Text figure 2 shows injury by the larvæ to an army biscuit, and Plate V, B, injury to cacao beans.

REPORTED INJURIES.

One of the firms which experienced trouble from this pest stated that the raw cacao beans, when received in bags, are stored in rooms about 16 feet high, some of the bags being piled nearly to the ceiling and others about 8 feet high. When the bags are disturbed the moths fly from between them and on examination numerous larvæ and cocoons may be found in such locations. Cocoons occupied or empty may be observed in almost any crevice in the walls of the storerooms.

Correspondents also note that the oldest cacao beans are, as a rule, the most heavily infested.

May 6, 1914, 10 moths of this species were placed in a rearing jar with cacao beans as food. One moth was still alive on May 27, but was found dead the following day, having lived 21 days without food. According to Dyar the tongue is completely absent in this moth, so it is unable to feed. No evidence of insect attack could be noted through the glass jar when examined on July 9, but when some of the beans, which had become moldy on account of the moist weather during this period, were opened, a mature larva and a cocoon containing a pupa were found. Attack was confined chiefly to beans that already had been injured more or less.

March 8, 1916, Dr. Carl Michel, United States Public Health Service, San Juan, P. R., furnished moths and pupæ, the latter in webbed-up rice, and stated that the species infests warehouses in Porto Rico, that the eggs are laid in sacks of cereals, and that the developing larvæ render the cereals unfit for human consumption. The merchants at San Juan claim that the rice is infested before it reaches that port and that nearly all of it is concentrated at New Orleans or Galveston for shipment. The claim is not made, however, although it is inferred, that the insect is shipped from the United States, but it seems more probable that the moth has been established in Porto Rico for a number of years. Agents of the Bureau of Entomology spent much time from 1908 to 1916 investigating insects injurious to rice and other stored products from New Orleans and Galveston, but they did not observe this insect at these or other ports. It may have been introduced recently through carelessness in vessels returning from Porto Rico containing foodstuffs on which it was able to subsist. On March 22 Dr. Michel sent additional specimens of larvæ in infested rice. The larvæ were all paler than were those reared from darker substances, such as chocolate and similar products, and as a result it was noted that the piliferous tubercles were plainly visible, whereas in the darker forms they were scarcely noticeable. September 12, 1916, numerous larvæ and some pupæ of this species were received in rice from the same source. The correspondent stated that some of the moths had been breeding continuously since the previous February, and that they thrived at room temperatures.

May 19, 1916, samples of rice infested by this species were again received, and on September 18 the Bureau of Chemistry reported that this specific shipment of rice was California grown, milled in San Francisco, and shipped via Panama Canal to New York City where it was held for about 30 days, and then reshipped to San Jaun, P. R., where upon its arrival the buyers rejected it because the market had declined, but not on account of "vermin," as the rice was apparently in sound condition. The rice was kept until October

30, and in the meantime the rice moth and other pests developed and the rice was condemned by the United States Government. Finally, the rice was shipped to New Orleans to be reconditioned, and was put into a condition satisfactory to the Federal authorities.

December 7 of that year, a chocolate firm in Pennsylvania, which previously had furnished specimens, wrote that the moths disappear with the arrival of cold weather and are not seen again until the following spring. During the late spring months and all summer they are in evidence. The greatest trouble is experienced from the laying of eggs by the moths on the finished chocolate and cocoa. The eggs hatch into larvæ and the customer naturally objects to "wormy" goods. Attempts were being made to avoid this as much as possible by keeping finished materials covered.

LIFE HISTORY.

The complete life history of the rice moth has not been ascertained. The progress which might have been made with other insects in similar investigations was prevented in this case by the fact that seldom more than two generations were obtained in a single rearing jar of cocoa or related substances. When confined in large numbers the larvæ, like others of similar habits, such as Ephestia, travel, evidently in an endeavor to secure a suitable location for transformation to pupæ, to a greater extent than do the other species. This might explain the fact that the pupal cases or cocoons usually are found either on the outside of the bags at point of contact in the piles, or in the folds of the burlap sacks, which provide more or less shelter. In the rearing jars, although small pieces of cloth were inserted to form shelters for the pupæ, the thick webbing spun by the larvæ completely covered the infested material, preventing the exit of the moths, which died without being able to reproduce. This fact is mentioned because it happened in the case of a half dozen rearing jars of large size (about 8 liters capacity).

It has been ascertained, nevertheless, that the insect requires only a short time to develop from larva to adult, this period being dependent on temperature. The entire summer period for transformation from egg to egg is between 28 and 42 days, or from 4 to 6 weeks, but this period would be prolonged considerably in cooler weather.

Better results attended rearing experiments with this species in infested rice from Porto Rico. From a lot of moths which deposited eggs about May 26 a new generation of moths began to issue July 8, this period having been passed in 43 days, or approximately 6 weeks. The temperature ranged from 52° to 82° F., reaching the maximum only on a few occasions, and the average or mean temperature for the experiment was from 68° to 70° F.

The question has been raised by importers and manufacturers as to whether or not it is possible to retard the development of the rice moth in order that control measures may be undertaken at desirable times. While it was not possible to undertake any experiments along this line, it is known from analogy that development could be considerably retarded by cold storage. The egg period might be extended from the normal length of time, 3 to 10 days, to about a month; the larval period to 6 months or more; and the pupal period from the normal of from 5 to 14 days to 4 weeks or longer, making a possible total of about 8 months.

While complete life-history data of this species would be desirable, what has been learned is sufficient to show that such life-history studies would not differ essentially from those of related species, such as the Mediterranean flour moth and the Indian-meal moth, and it has been developed that there is a practical certainty of four generations annually and a possibility of as many as six in high temperatures.

ASSOCIATED INSECTS.

The fig moth (*Ephestia cautella* Walk.), as previously stated, has been associated with this species in infested rice and cocoa products. In one rearing jar containing the rice moth breeding in cocoa, received June 18, 1915, the larvæ of the latter were full grown on August 27. The jar was examined again on September 10 and apparently contained only the fig moth with its larvæ. This latter had evidently "run out" the former, its larvæ perhaps feeding on the larvæ and pupæ of the rice moth, which in nature is not an unusual occurrence.[1] Some, however, remained, and in a few days the rice moth reappeared. In this particular rearing cage the fig moth must have deposited her eggs through the mesh covering the jar, although this was decidedly thick and closely woven. Fig-moth females have been known to do this in previous instances.

The Indian-meal moth (*Plodia interpunctella* Hbn.) developed in great numbers in a lot of chocolate in which the rice moth had been reproducing abundantly, completely devouring the edible material and then perishing.

It may be noted that when closely confined with edible material the three moths mentioned, in common with others which feed upon stored products, frequently perish because of the compact webbing which prevents escape and the lack of moisture which produces excessive drying of their food supply, curtailing the longer reproduction period of the species.

[1] The larvæ of the cabbage worm (*Pontia rapae* L.) have been noted feeding on the eggs of the cabbage looper (*Autographa brassicae* Riley). The corn earworm (*Chloridea obsoleta* Fab.) is also well known to be cannibalistic.

Some forms of beetles, however, are able to continue feeding in the absence of moisture until the supply of food is exhausted.

The saw-toothed grain beetle (*Silvanus surinamensis* L.) has been found in several instances associated with the rice moth. Obviously it plays the same rôle with this species as with other moths—a scavenger, although a decidedly noxious pest.

The rust-red flour beetle (*Tribolium ferrugineum* Fab.) has been observed in the same situations as the saw-toothed grain beetle.

The lesser grain-borer (*Rhizopertha dominica* Fab.) was received in rice from Porto Rico associated with stages of the rice moth.

The Siamese grain beetle (*Lophocateres pusilla* Oliv.) was observed breeding in numbers in a sample of Porto Rican rice some time after receipt, showing that the immature stages were present at an earlier date.

The rice weevil (*Calandra oryza* L.) was present in small numbers in most of the samples inspected. It was noticeable in broken rice that the beetles which developed in such small quarters were not as large as those which are found in soft kernels of corn and wheat. The color of the beetles taken in broken rice was brighter and they had the appearance of being a distinct species.

HISTORY AND LITERATURE.

While the rice moth probably has been present in Europe for many years, it was not until 1866 that it was discovered in York, England, and described as a new species by Stainton (1). It was found in imported dried "currants" (*Passulae corinthicae*), called "Corinthian currants," but in reality a well-known species of grape. In 1875 Barrett (2) mentioned the occurrence of this species in fruit warehouses in London, together with other insects of similar habits. In 1885 (3), 1893 (4), and 1901 (7) Ragonot wrote, in technical articles, in regard to the classification and characters of this species, without reference to its injurious habits. In 1895 Meyrick (5) gave a brief technical description of the adult, stating that the larva occurs in dried "currants." In 1897 (6) the author mentioned this species in a list of insects likely to occur in this country in dried fruit. In 1909–10 Fletcher (8) recorded the species as occurring in rice from the West Indies.

In 1913 Durrant and Beveridge (9) wrote the most extensive account of the insect which had appeared to that date, referring especially to its occurrence in army biscuits and the temperature which would destroy this and other species of related habits. An article dealing with this insect, by Otto H. Swezey (10), appeared the same year.

In 1908 the rice moth came to the attention of Mr. Jacob Kotinsky of the Bureau of Entomology, at that time in Hawaii, who found it

breeding in a feed warehouse in Honolulu in July. On July 10, 1909, it was captured at Kaena Point by Mr. Swezey. The latter part of the same month moths were found emerging from a package of cracked wheat obtained from a Honolulu grocery. Mr. Swezey expressed the opinion that although the species is a European moth apparently not recorded at that time in the United States, it certainly must have reached Honolulu from the United States.

The habits of the moth are well described by Barrett (2). He states that when disturbed in flight, unlike Ephestia and Plodia, it darts down in a zigzag and almost immediately comes to rest. Toward evening the males run about, quivering their wings in a peculiar manner. The moth shows considerable skill in selecting for a resting place the projections of rough beams, to which, owing to its rough, blunt head and closely folded wings, it bears so close a resemblance that Barrett states he has taken specimens between his fingers before he could satisfy himself that they were not projecting splinters. This can be readily appreciated by reference to Plate I, B, which shows the moth at rest. The moth is peculiarly sluggish, even more so than those of the other genera. Barrett writes of this and of a related species (Ephestia) that they were being replenished constantly from imported dried fruits, since every cargo of fruit swarmed with the larvæ, some of which died from change of climate and other causes, but many of which came to maturity. He states that it is obvious that places in which old "currants" have been stored are the most potent sources of infestation, the new fruit coming into harbor during the month of September when the moths are already plentiful. He believed that the different species occurred in about equal numbers and was certain that they had formed a settlement from which it would be no easy task to expel them.

CONTROL MEASURES.

Warehouses and other structures in which the rice moth has become established should be cleansed thoroughly. Any bags which contain or have contained infested rice or other cereal, cacao beans, cocoa or similar material, or dried fruits should be fumigated; all corners, cracks, and crevices which may harbor the insect should be brushed out; and all refuse promptly destroyed by burning. The walls and floors then may be washed down with a soluble creosote disinfectant, or a solution of common salt. The brushes used should be stiff and strong, and every point should be reached so as to make the compartment perfectly clean.

The machinery also should be cleaned thoroughly and the entire plant fumigated with hydrocyanic-acid gas. In small plants either carbon disulphid or sulphur dioxid may be employed for fumigation,

but if the buildings are so constructed that heat of 120° to 130° F. may be applied for several hours, the same result will be accomplished.

Secondhand bags should not be used without first disinfecting them and bags previously used for the transportation of cacao beans or other food materials which the rice moth is known to attack should be examined for the presence of the insect in its various stages. When insects are found it is best to establish a quarantine bin, room, or fumigator in which the infested bags may be thoroughly baked or fumigated before they are taken into the main building. If it is desired to fumigate a compartment containing bags filled with cacao beans, rice, or similar material the bags should first be brushed off carefully and the tiers of bags so separated as to leave air space between in order that the gas may penetrate the contents more readily. Even after fumigation there is always a possibility that a small percentage of the insects may remain and revive.

DESTRUCTION BY HEAT.

Treatment of insect-infested stored products by heat is by no means a new remedy, but large-scale work with this method had not been conducted to any extent until about 10 years prior to the time of writing. This method appears to have been first successfully used in the control of mill pests at that time by the Kansas Agricultural Experiment Station, for the control of both the Mediterranean flour moth and the Indian-meal moth. Soon thereafter Mr. C. H. Popenoe, of the Bureau of Entomology, conducted experiments in Virginia, under the writer's direction, which were quite successful against both of these pests.

The heat method is equally applicable for the rice moth, although it is valuable only for mills or other structures heated or operated by steam, since it presupposes the installation of necessary heating pipes and radiators. The temperature required, from 120° to 130° F., can be obtained readily in a mill provided with sufficient radiation surface to maintain a winter temperature of 75°. A warm, quiet day should be selected for best results, and the temperature after being reached should be maintained for 8 hours or more in order to insure penetration. Should additional radiation surface be required, it may be provided by the installation of temporary supplementary coils of $1\frac{1}{4}$-inch pipe, which will operate to best advantage if placed near the floor. In mills where a complete installation is required, radiators should be calculated on a basis of 1 foot of heating surface ($2\frac{1}{3}$ linear feet of $1\frac{1}{4}$-inch pipe) to from 50 to 100 cubic feet of space, depending on the construction of the building and the situation of the coils. The maximum figure should be applied to the lower floors.

A steam pressure of from 75 to 100 pounds may be employed advantageously. Since bags of compact material are heated to the center with difficulty, so far as possible they should be separated before treatment to facilitate uniform heating, for insects and their larvæ become more active upon the application of the heat and may work their way to the center of the bags in their efforts to escape it.

Better results may be obtained by providing the radiators with water traps or vents.

Rice and cacao beans should not be exposed to a temperature above 130° F. for more than one hour, as excessive splitting takes place in rice, especially if bleached, and, owing to the excessively oily nature of cacao beans, they may become rancid.

Germination in the case of some seeds, such as peanuts, is not affected even by an exposure of six hours to a temperature as high as 140° F., but it is best to be on the safe side in the treatment of commodities affected by this moth until we have had more experience along this line. It should be added that a temperature of 140° F. is fatal to most forms of insect life in a short time—larvæ, pupæ, and adults. The Indian-meal moth, it has been learned by experiment in the Bureau of Entomology, dies in less than half an hour when so exposed.

FUMIGATION METHODS.

HYDROCYANIC-ACID GAS.

For the fumigation of buildings and other structures inhabited by the rice moth, the hydrocyanic-acid gas process is the most useful. Indeed, it is now the standard remedy for practically all insects affecting stored products. It has been in use for this purpose for about 20 years and most progressive millers are familiar with the method of application. Information in regard to hydrocyanic-acid gas fumigation has been furnished by the Bureau of Entomology in various bulletins and other publications. In the earlier ones the use of cyanid of potash or potassium cyanid was advised, but owing to conditions brought about by the war it is now impossible to secure this chemical, and as a result cyanid of soda or sodium cyanid is being used, and while somewhat expensive, is much cheaper than the corresponding potash salt. The formula is as follows:

Sodium cyanid	avoirdupois ounce	1
Sulphuric acid	fluid ounces	1½
Water	do	3

Information in regard to this method is furnished in Farmers' Bulletin 699, "Hydrocyanic-acid Gas Against Household Insects." While this, as the title shows, is especially for dwellings, the methods advised can be adapted readily to mills and storehouses.

Hydrocyanic-acid gas, it must be stated, is the most poisonous substance in common use, but it is still employed very extensively in fumigating mills and dwellings, and if the directions in the bulletins cited are carefully carried out there is really no danger to human beings.

CARBON DISULPHID.

Before the general adoption of hydrocyanic-acid gas as a means of fumigating buildings, carbon disulphid was considered a standard, and it is still of value, particularly on a small scale, as a substitute for hydrocyanic-acid gas. It is extremely inflammable, however, which has led to its abandonment in many localities. Directions for its use are given in Farmers' Bulletin 799[1] "Carbon Disulphid as an Insecticide."

SUMMARY.

1. The rice moth (*Corcyra cephalonica* Staint.) has been known to occur in the United States only since 1911, and was not identified until 1916.

2. Its origin is unknown, but it has been introduced at many points in other continents and is as yet not strictly cosmopolitan. It has been found commonly in England, where it was introduced in rice, chiefly from India and Burma, and also in dried fruits.

3. Its habit of feeding on cacao beans is probably an acquired one. Evidently it is inclined to be omnivorous, since it breeds in rice, dried fruits, the various products of cacao, such as cocoa, cacao shells, and sweetened and unsweetened chocolate, ship biscuits, and sesame seeds. It displays, however, no partiality for any of these food substances.

4. Its complete life history has not been traced, but, like other indoor species, it reproduces nearly the year around under average conditions. In the United States infestations appear to die down from time to time, but are stimulated through new shipments of cacao beans from South America and Central America.

5. It produces copious and dense external webbing to which food materials, such as rice, cocoa, and other matter, strongly adhere. In this respect its work and injury resemble those of the fig moth (*Ephestia cautella* Walk.) and related species, and the Indian-meal moth (*Plodia interpunctella* Hbn.).

(6) While it has been recognized only from western Pennsylvania and Porto Rico, it occurs without doubt at other points, and dealers in rice, chocolate, and similar imported dry edibles should keep a

[1] The Farmers' Bulletins mentioned may be obtained free on application to the Division of Publications, United States Department of Agriculture.

lookout for the species to prevent it from gaining entrance and becoming established in large warehouses and similar plants.

7. It will undoubtedly increase in injuriousness in time unless proper measures are taken to stamp it out by thorough treatment.

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LESSONS ON POTATOES FOR ELEMENTARY RURAL SCHOOLS.

By ALVIN DILLE, *Assistant in Agricultural Education.*

CONTENTS.

INTRODUCTION.

Importance.—The potato is one of the most widely cultivated of the agricultural plants, and, next to Indian corn, it is the most important contribution of America to the food supply of the world. Probably no crop except rice is eaten by a greater number of people. In the more thickly populated regions of Northern Europe, the potato is now the most important of human foods, furnishing about 25 per cent of the food of the continental and English peoples. Only the Oriental peoples exist without it. Not only are the tubers used for food, but they have important industrial uses. The plant is allied botanically to several powerful narcotics, such as tobacco, henbane, and belladonna, and also the tomato, eggplant, and pepper.

As our American population increases, the potato will become more and more important in this country, there being no other crop which will give such a large yield of food suitable for man, under such varying conditions.

Educational value.—The importance of the potato crop as briefly indicated above and the fact that it can be grown successfully in every State in the Union, should give it a place in courses in general

agriculture and farm crops in nearly every school where such subjects are taught. At least one aim in the teaching of agriculture should be the training of farmers for the future, and as a result of such teaching the world should be better fed. The immediate aim in teaching this subject may be to aid in securing a production of better potatoes at a lower cost, but it may also be a medium for developing and applying many of the general principles of plant production. Applying these lessons to a home project will not only have greater agricultural value, but also will do much toward developing the student into a self-reliant husbandman.

Sources of information.—Nearly all the subject matter for class discussion and instructions for home project work will be found in bulletins available either free or at a small cost. Almost every State college of agriculture has published potato bulletins, and in many cases the extension service has issued circulars for school and club use. These may be obtained by addressing the dean of the agricultural college.

The Farmers' Bulletins of the United States Department of Agriculture cover most of the topics to be studied, and are suited to the use of the pupils. These bulletins may be obtained free as long as the supply lasts by applying to your Senator, Representative, or Delegate in Congress, or to the Division of Publications, United States Department of Agriculture, Washington, D. C. When this free supply is exhausted, a limited number are for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents each.[1] Seed houses frequently issue pamphlets on potatoes, and these may be obtained free. Farm journals from time to time publish articles on potatoes. These should be clipped and mounted. A good way to keep bulletins and clippings is to file them in pasteboard cases, grouping these references by subjects. Encourage pupils to bring reference material to school.[2]

Illustrative material.—As potatoes may be secured at any time of the year, there is no excuse for attempting to study the potato without having specimens at hand which represent common varieties grown in the district. The potato plant in the field should be studied during the different stages of development. Especially should the relation of the new tubers to the seed tuber and the root system of the plant be noted. If no plants are available, a diagram showing the plant as a whole will be useful. (The figure may be copied on the

[1] Classified lists of department publications on different phases of agriculture for teachers' use, together with other information for teachers of agriculture, may be obtained from the Division of Agricultural Instruction, States Relations Service, United States Department of Agriculture, Washington, D. C.

[2] Write to the Division of Agricultural Instruction, referred to above, for a circular on the essentials of a school library, describing a simple method of filing reference material.

board or made into a chart.) Charts showing the composition of the potato and its relative food values should also be made. Pictures clipped from bulletins, showing types of potatoes, may be mounted for class use. The teacher should keep in mind always the value of illustrative material in arousing interest and vitalizing the study of the subject. Continuous efforts should be made to visualize the lessons.

The survey.—One of the best means by which the teacher may become informed about the potato interests of the district is the potato survey. This survey may be made either by the teacher alone, or with the assistance of the pupils, the latter method being more easily carried out. The survey should include such questions as size of farm acreage in potatoes, soil, varieties of potatoes, yield per acre, value, bushels marketed and bushels used at home, storage methods, etc.

The general district survey as a means of obtaining agricultural information and as a basis for agricultural instruction may be set forth in the following outline:

THE DISTRICT SURVEY.

The aims—

To know the district.
To obtain a basis for teaching agriculture.
To interpret better State and national data.
To observe progress by successive surveys.
To provide vital correlation material.

The method—

Preparation of adequate lists of questions.
Collection of data, all farms, each pupil.
Tabulation of data by farms.
Summary of tabulations.
Mapping survey data.

Utilization as—

Basis of class instruction in agriculture.
Problems, reports, and other correlations.
Means of developing home projects.
Entering wedge for community service.

The home project.—It is agreed by teachers of agriculture that instruction in this subject should follow certain definite lines.

1. It should be seasonal; that is, a monthly or seasonal sequence should be followed out as far as possible in the presentation of these lessons.
2. It should be local in its interests and development.
3. It should meet the interests of the pupils.
4. It should be practical.

The home project affords the best means for meeting these conditions, especially the practical condition.

The term "home project" applied to instruction in agriculture includes each of the following requisites: (1) There must be a plan for work at home covering a season more or less extended. (2) It must be a part of the instruction in agriculture of the school. (3) There must be a problem more or less new to the pupil. (4) The parents and pupil should agree with the teacher on the plan. (5) Some competent person must supervise the work done at home. (6) Detailed records of time, method, cost, and income must be honestly kept. (7) A written report based upon the record must be submitted to the teacher. This report may be in the form of a booklet. The club project should be identical with the home project from the school point of view.

A potato project may take one of two different lines. It may be a production project where the chief aim is to increase the production per acre at the lowest cost; or it may be an improvement project where the aim is to improve, by careful selection, the quality and quantity of a variety of potatoes grown. The potatoes produced on the first project will be placed on the general market for consumption, while the surplus crop produced on the second will, after selection, be sold to dealers or producers for seed potatoes. The first type adapts itself the better to general conditions.

Correlations.—Some suggestions have been made in connection with each lesson, as to the use of this subject in vitalizing the other subjects in the curriculum. These correlation suggestions are not intended as a part of the lesson in which they appear, but should be used with recitations in other subjects. The teacher should seize every opportunity to link up the recitation with the life of the community and to give the instruction purpose and direction by connecting it with the problems of the home and farm.

LESSON I.

Subject.—Selection of seed potatoes in the field.

Problem.—To improve the potato crop year by year. To develop a strain which will produce well and with uniformity under local conditions.

Sources of information.—Farmers' Bulletin 533; Department Bulletins 176 and 195; bulletins and circulars from the State college of agriculture.

Illustrative material.—Four or five typical specimens of each variety of potatoes grown in the community. Typical plants of each variety. The entire yield of one good hill and of one poor hill, kept separate for contrast. Specimens of unmarketable potatoes showing defects. Pictures of ideal potatoes of the standard varieties should

be mounted and kept for class use. Obtain potato "balls," if possible.

Class exercise.—The first step in the selection of seed potatoes is the inspection of the field while the plants are yet green and vigorous. Why? Select and mark plants which are true to type, free from disease, stocky, and vigorous. The typical plants of the varieties grown in the district may be brought to class and their characteristics studied. Why is a vigorous top growth essential?

At the time of harvesting, select superior tubers from the best hills in the areas previously worked. Choose productive hills which have a good number of fairly large tubers and very few culls. If the grower is interested in selecting and breeding a superior strain, it may be desirable to keep separate the product of several especially good hills. All tubers selected should be normal in size, shape, and color, and free from scab and other signs of disease. Somewhat immature tubers make better seed.

What varieties, early and late, are most common in this district? Which have only a local reputation? Which market readily? Why is it not as well to plant the seed from the "seed ball" as to use the tubers? Why not make the selection from the bin in the spring?

Practical exercises.—Have each pupil practice identifying in the classroom the varieties of potatoes to be found in the district. If any have peculiar local names, try to classify them. (See Department Bulletin No. 176.) Have each variety examined to observe: (1) Plants—size, branching, stockiness, color, and freedom from disease. (2) Leaves—size, color, and peculiarities. (3) Color of the flowers. (4) In the spring the shape and color of the sprouts are important. (5) Tubers—shape, normal size, color, and markings of the skin, number and depth of eyes, color and condition of flesh.

Arrange for a field trip during which the class shall examine some good potato fields and select the sections of the field from which the seed should be taken, giving reasons for the choice. If the owner is willing, have a few hills dug and the plant and tubers discussed. Show that the tuber is a stem and not a root. Note any peculiarity of any variety as adapted to certain soil or climatic conditions. Have pupils apply this lesson in their own home project.

Correlations.—Have the pupils collect and compile the district survey of the potato crop as suggested by the form given below. This will provide ample correlations in arithmetic, language, and spelling. Dictate a list of questions to the class and divide the farms of the district among them so that all may be reported on soon. Include also, questions as to methods, prices, shipping rates, weights, capacity and kinds of packages, disposal of culls, and other data. Some of the information can not be given before harvesting.

DISTRICT SURVEY OF THE POTATO CROP.

Name of district_____ Date_____

Farmers.	Tillable acres.	Acres in potatoes.	Per cent of land in potatoes.	Total crop.		Per acre.		Bushels sold.	Rate per bushel.	Income.		Bushels for home.
				Early.	Late.	Early.	Late.			Gross.	Net.	
Mr. A												
Mr. B												
Etc												
Total												

Potato crop summary_____ Date_____

Varieties.	Acres planted.	Yield.		Acre yield.	Bushels sold in field.	Price per bushel.	Total income.	Bushels stored for—			
		Good.	Culls.					Home use.	Home seed.	Market.	Seed for sale.
Early:											
Early rose											
Cobbler											
Etc											
Etc											
Late:											
Green Mountain											
Rural											
Etc											
Etc											
Total											

LESSON II.

Subject.—Harvesting and grading potatoes.

Problem.—To study the farm practice in harvesting and grading potatoes with a view to finding the most efficient methods of handling the potato crop.

Sources of information.—Farmers' Bulletin 753; Document, Markets, 7; circulars and bulletins from State college of agriculture; articles in the farm papers.

Class exercise.—The application of this subject to the seasonal practice of the district and to the projects of the pupils will call for modifications to suit each case. Late potatoes are harvested in the Northern tier of States from the latter part of August to the middle of October. In the Northern States the main crop is planted during the summer and the harvest begins after the middle of October. In all cases this lesson should be taken at such a time that the class may observe or participate in the harvesting and grading soon after the school work in the same subject. The following items of farm practice in the handling of potatoes should be noted:

1. The time to dig will vary with market conditions and other factors. They should be dug as soon as vines die, earlier if mature.

2. Small areas may be dug by hand, with hooks or potato forks. All large acreages are now dug by machinery.

3. Make field trials on the given soil before adopting any digger. Unless the field has been kept very clean it will pay to mow, rake, and burn all weeds before digging. Weeds and tops tend to clog digger.

4. After digging, let tubers lie on ground long enough for dirt to dry out, also to toughen the skin against bruising.

5. Careful handling pays at every stage. Bruised or cut potatoes decay readily and every tuber lost reduces the profits. Hardening process must not be prolonged to the extent of sunburn (especial care with some varieties).

6. Sorter may be used in field if weather permits. Potatoes sold in field weigh more than stored potatoes.

7. The careful sorting and grading of potatoes is quite as important as the grading of fruits.

Practical exercises.—Discuss the methods of harvesting potatoes in this district and elsewhere. Arrange for the class to take a field trip to observe the methods of harvesting and sorting potatoes at one of the most approved and successful potato farms in the district. Discuss methods of sorting. Need of keeping varieties separate Sorting by sizes. Keeping out diseased potatoes. Find out what the farmers are doing with culls. If potato-digging machinery is used, make a study of the different machines with a view of finding out which one is best adapted to the soils of this section. Visit a dealer and inspect the machines he carries in stock. What is the common method of sorting potatoes? What sorting machines are used? What type seems to be the best adapted for its work? Note the methods of handling the crop, such as packing and hauling.

Correlations.—Arithmetic: Use local yields and prices and make problems suited to advancement of the class. Obtain State records of potato crop and the market price for further problems.

Language: Utilize for written or oral exercises such topics as: "A trip to observe potato harvesting," "How to sort potatoes," "Potato-harvesting machinery."

LESSON III.

Subject.—Marketing potatoes.

Problem.—To discover the best farm methods of marketing potatoes in order that they will bring the highest market price and reach consumer in first-class condition.

Sources of information.—Farmers' Bulletins 365 and 753; Office of Secretary, Circular 48; Document, Markets, 17; publications from State college of agriculture; articles in farm papers.

Illustrative material.—Procure samples of typical marketable potatoes of both grade No. 1 and grade No. 2, using varieties common in district, specimens of imperfect and diseased potatoes, pictures and drawings of various containers for marketing potatoes, samples of crates and baskets for marketing small lots, a map of the State and the United States showing railroad routes to the chief markets for the district, pictures or diagrams showing methods of loading in part or in full carload lots. Procure samples of potatoes for sale on the market and compare with the samples of typical grades.

Class exercise.—Discuss the following topics with the class:

1. The grading of potatoes for market, stressing quality as well as uniformity.
2. Preparing for shipping—the package, crate, barrel, box, sack; advantages and disadvantages of each. What package is commonly used in this district?
3. The market for the crop, local and shipping.
4. Prevailing prices.
5. Cooperative shipping organizations.
6. Are the potatoes shipped in small lots or by the carload?
7. What is the general practice regarding the selling and shipping—potatoes sold in the field, f. o. b. the car, shipped to a commission merchant; open shipment, shipped with bill of lading attached, or shipped billed to the shipper?

Practical exercises.—Plan a field trip to a potato farm or a potato storage house to observe the methods practiced in preparing potatoes for market and shipping. If potatoes grown in the district are sold in local markets, visit these markets to observe the way these potatoes are sorted and handled. Note prices for same and compare with prices received in other markets and when shipped. If there is a community marketing association, the class should make inquiries as to their methods of handling and shipping the crop, the number of bushels handled, markets supplied, and net price to shippers. Discover what use is made of culls. A class discussion as to the proper way to handle culls will be profitable.

Correlations.—On a map of the United States locate the chief markets supplied. What railroads carry the potatoes? Locate the potato-growing sections of the State and of the United States. These exercises will afford good practice in geography.

Arithmetic: From the information gathered in the practical exercises and class study make problems adapted to this lesson and grade of the pupils.

Language: Written or oral exercises on "Grading potatoes," "Preparing for shipment," and "Potatoes on the local market," will give abundant practice in language.

LESSON IV.

Subject.—Winter storage.

Problem.—The preservation of the potato crop during the winter so that it may be available either for market or home use.

Sources of information.—Farmers' Bulletins 847 and 879; bulletins and circulars from State college of agriculture; articles in farm papers.

Illustrative material.—Clip from farm journals pictures showing various types of storage and mount these for class use. From bulletins and farm papers enlarge drawings of pit storage; show a cross and a vertical section. Do the same for a storage house, showing floor plans and vertical sections, giving arrangement of bins and shelves. If possible, secure photographs of community-storage houses and mount them for classroom use. Construct charts showing the advantages of storing products and the essential factors of storage. Small models of wooden storage houses may be constructed by the members of the class.

Class exercise.—The following topics should be discussed with the class:

1. Importance of storage.

2. Object of storage—economy, holding a more or less perishable product in a salable condition as long as possible, providing for a uniform market supply.

3. Essential factors in storage—(*a*) product well matured, (*b*) careful handling, avoid bruising, (*c*) uniform temperature after storing, (*d*) the moisture content of the air, (*e*) exclusion of light.

4. Types of potato storage—(*a*) in basement of house; storage rooms constructed in cellars, plans, ventilation, containers, (*b*) outside storage caves or cellars; advantages, location, construction; storage construction in mild regions, storage construction in regions of severe freezes, concrete storage cellars, advantages, site, construction, (*c*) storage in banks or pits; location, how constructed, ventilation, advantages, disadvantages, (*d*) community storage house; plans, construction, how conducted, advantages.

Practical exercises.—Make a study of the farm practice generally observed in storing potatoes. What method of storage is most common? What other method might be more effective? What is the purpose of storing potatoes, for the home or for the market? Is there community potato storage in the district? How is it constructed? How managed? What quantity of potatoes is commonly stored there? What is the cost of storage? How well is it patronized? Does it seem to be successful? If possible, visit with the class a farm where potatoes are being stored and note the methods used in preparation for storing and the methods used in storing. Note the construction of any storage houses that may be visited in the district.

Correlations.—A report on the general practice of the district in storing potatoes will provide good exercises in oral or written language. A detailed account of the making, filling, and covering of a storage pit will also provide good language material. Another interesting language study will be a comparison of the storage methods of the warmer regions with those of the colder regions.

Arithmetic: Problems involving the amount and value of potatoes stored will be suggested by this lesson. The amounts from each farm and totals for the district. The values of the potatoes on the fall market compared with the value on the spring market will provide further material.

Geography: Locate the sources of potatoes shipped into the district. How near does the district store its own supply of potatoes? If the stored potatoes are sold, trace their route to the consumer.

LESSON V.

Subject.—Potato judging.

Problem.—To be able to identify the leading varieties of potatoes and to recognize the chief characteristics of each variety.

Sources of information.—Farmers' Bulletin 533; Department Bulletin 176; bulletins of State college of agriculture; extension leaflets; circulars; score cards from State college of agriculture.

Illustrative material.—From seed catalogues and farm papers, clip and mount pictures of varieties of potatoes. From the farmers or from dealers, secure at least three typical specimens of the different varieties of potatoes raised in the district or on sale in the market. These should be carefully taken care of for class study.

Class exercise.—This lesson is essentially a lesson of practice in studying the varieties of potatoes. The following leading factors should be noted:

1. Trueness to type, uniform in size, shape, color, etc., according to variety of class; no mixture.
2. Uniformity: General uniformity in shape, length, and circumference.
3. Shape of tuber: Round, oval, or long, according to class or variety.
4. Color: Conforming to class or variety and free from green.
5. Size: Medium—average weight for early varieties 8 ounces, or late varieties 12 ounces.
6. Eyes: The eyes of the potato should be medium deep, well defined, and not too numerous. Deep eyes cause waste in paring. Shallow eyes are low in vitality, and too many eyes denote poor stock.
7. Skin: Smooth without cracks or blemishes. The skin may be whitish, brown, reddish, yellowish brown, blue, or black, depending

upon variety. It may be thick or thin, tough or brittle. A thick, fairly tough skin is preferred.

8. Flesh: When cut, firm, clear in color, free from hollow center, dark rings, discoloration, woodiness.

9. Freedom from blemishes: No scab spots or skin ruptures from any other diseases, no cuts, bruises, scratches, or other defects.

Practical exercises.—Students should practice on identifying the different varieties of potatoes until they can be recognized at sight. The chief characteristics noted above should be studied and students taught to observe varieties from type. Use score card suggested below or ask the State agricultural college for enough to supply the class. Require the students to mark the points on the card. Compare with a typical potato (either a real potato or a good picture of one) to note any difference. Hold judging contests in which the students will be required to judge and score the different varieties. Ask for the help of the county agent in these contests. Make this work of a practical nature, and drill until the pupils are able to recognize readily the different kinds of potatoes and to score them fairly accurately. The following form of score card may be used:

POTATO SCORE CARD.

Variety—Name_____

Scale of points.	Standard.	Student's score.	Corrected.
Trueness to type	20		
Uniformity	15		
Shape	20		
Color	5		
Size	10		
Eyes	5		
Skin	5		
Flesh	5		
Freedom from blemishes	15		
Total	100		

Scored by_____ Date_____

NOTE.—Give directions for using the above card.

Correlations.—Language: Oral or written reports on the kinds of potatoes grown in the district or in the State; how to judge potatoes; a history of the chief classes of potatoes will all provide abundant language work.

History: Write a history of the potato, an account of its introduction into Europe, the story of Luther Burbank and the Burbank potato.

Arithmetic: If potatoes scoring 100 points are worth $2.50 per bushel, what would be the value per bushel of the potatoes scored,

basing their worth upon the points scored? Rating in this manner, what would be the loss at current market prices, on a 10-acre crop of each variety scored if the yield was 175 bushels per acre?

LESSON VI.

Subject.—The potato tuber (and plant) structure.

Problem.—To understand methods of potato requirements for growth.

Sources of information.—Farmers' Bulletin 533; Department Bulletin 176; bulletins from State college of agriculture.

Illustrative material.—Potato tuber specimens. The entire plant showing roots and clinging tubers. Obtain, if possible, entire plant of the tomato, tobacco, and jimson weed and other relatives of the potato. If plants are not obtainable, a diagram showing the potato plant as a whole will be found useful. Pictures of the related plants will be found in publications and may be used also. Charts may be used to show structure of the tuber and to illustrate types in connection with such specimens as may be obtained.

Class exercise.—The potato plant. Discuss with the class the following topics:

1. The potato-plant family, cultivated members, nature of some of the wild relatives.
2. What resemblances do you note between the tomato and the potato? Compare the fruit of the potato with the fruit of the tomato.
3. Make a study of the stem, branching flowers, and seed balls.
4. Note differences in the plants and flowers of different kinds of potatoes.
5. Why do not all varieties of potatoes produce fruit?
6. The tuber: Note arrangement of eyes upon the tuber and trace their relationship to buds. Distinguish clearly between seed potatoes and the real seed produced in the fruit.
7. Study the root system of the plant and note the relation of the new tubers to the seed tuber.
8. Cut the potato tuber into sections and note its different parts.
9. What resemblance can you find between the structure of a tuber and the structure of the green stem of a plant?

Practical exercises.—Students should be required as far as possible to study the complete plant of the potato and related plants. The characteristics of the plant should be noted and comparisons made between the different varieties of potatoes. Contrasting studies of the potato and related plants should be made. It should be clearly shown that the tuber is an underground stem and not a root. Cross and longitudinal sections of the tuber should be made and the

various parts of its structure noted. What distinguishes the potato from the other members of the nightshade family? A study of the characteristics of the various types of potatoes should be made with a view of aiding the student to identify the different groups.

Correlations.—Drawings of a tuber, showing parts, and of sections showing structure should be made. In studying the entire plant the student may sketch the plant or make a copy from a chart.

Language: Look up the nightshade family of plants in a good reference book, and bring to class a written report on same. Make a written or oral report on the differences between the potato and tomato or other members of that family. Write an account of the usefulness of the nightshade family.

LESSON VII.

Subject.—Place of potatoes in the rotation.

Problem.—To study the place of potatoes in a rotation in order that the greatest yields may be made and soil fertility maintained.

Sources of information.—Farmers' Bulletin 365; a good reference text; bulletins from the State college of agriculture.

Illustrative material.—Comparative charts showing yields of potatoes grown in a rotation and those grown continuously on the same field; field diagram showing suggested 3-year, 4-year, and 5-year rotations; diagram of crop rotation with potatoes actually being carried out in the district. All these will make helpful illustrative material.

Class exercise.—Discuss with the class the following topics showing the advantage of growing potatoes in a rotation with other crops:

1. Plant diseases often become rapidly worse in the continuous cropping system, which has often been the case with potatoes. The class may be shown how modern scientific methods of care of seed selection, disinfection, spraying, and other details of culture somewhat reduce this danger.

2. In the business management of the farm rotation reduces the danger of excessive losses in seasons of low prices or of poor yields and arranges the work of the farmer through the season to better advantage.

3. Weeds are more easily controlled under a system of rotation. The high value of the potato crop pays for thorough tillage and care which cleans the soil of weeds for the rest of the rotation.

4. Insect pests are kept down more easily under rotation.

5. The high cash value of the potato justifies considerable expenditure for fertilizers, and justifies the use of more of the time of the rotation in producing organic matter to be returned later to the

soil. The thorough culture, late digging, and winter exposure of soil, especially in the Northern States, rapidly use up the soil organic matter. The cheapest and easiest way of replacement is by rotation with grass, clover, and other hay crops which have a money value as food for animals, and also leave large amounts of organic matter in the soil from their roots and stubble, as well as that in the manure from the hay feed.

6. Different plants draw on the plant food in the soil in varying proportions, consequently a rotation of crops utilizes the plant food to better advantage than a single crop grown continuously.

7. Though the potato sends its roots deeper than some other crops, others, like clover and alfalfa, root much deeper. These bring up fertility from the subsoil, and the roots of the potatoes following are able to grow lower, even in hard clay soils.[1]

8. The theory has been advanced that plants in their growth throw off in the soil toxic substances which, by accumulation, become injurious to succeeding crops of the same plant, but not to others. Rotation avoids this possible danger.

9. The physical condition of the soil for succeeding crops is improved by the thorough culture given the potato. Examples of this are the use of wheat following potatoes without plowing in the fall, and oats without plowing in the spring.

The net return of the rotation as a whole must be the deciding factor in the choice of crops. The potato gives such large cash returns to the acre and responds so well to the use of fertilizers, that usually it is the most important crop of the rotation in which it is grown. Wherever this is true, the choice of other crops to go with it is largely governed by the effect on the soil for the production of the potato.

Some suggested rotations are:

1. Potatoes—oats—grass and clover—grass and clover—potatoes.
2. Potatoes—wheat—clover—potatoes.
3. Clover or alfalfa—a small grain—potatoes.
4. Potatoes—wheat—clover—potatoes.
5. Potatoes—small grain—clover.
6. Potatoes—corn—cowpeas.
7. Winter rye—clover—potatoes.
8. Small grain two years—clover—potatoes.

Practical exercises.—Have the class make a study of the district farm practice in potato growing. What are the common rotations? What examples can be found of the continuous cropping? What differences in yields may be noticed? Does the acreage in potatoes on the farms of the district justify any plan of rotation of crops? (See potato survey. If possible, visit one or more farms where rota-

[1] Colorado Sta. Bul. 216.

tions in connection with potato crops are being carried out and note general conditions of fields, crops, and tillage.)

Correlations.—Correlations in language will be suggested in the matter of written or oral reports on field trips and observations made in the study of the farm practice of the district in rotations.

Drawing: The construction of the charts suggested under illustrative material will afford practice in drawing.

Arithmetic: Problems on yields of potato crops on both rotation plan and the continuous cropping plan will be suggested in the study of this lesson.

LESSON VIII.

Subject.—Soils—kind, preparation, fertilizers, etc.

Problem.—To study kinds of soils suitable for potato growing, their preparation and fertilizing.

Sources of information.—Farmers' Bulletins 365, 386, and 407; bulletins from State college of agriculture.

Illustrative material.—Collect soil samples from the potato farms of the district; bottle and use in class for comparison. Collect in a like manner the various commercial fertilizers used for potatoes. Clip and mount pictures from farm papers, circulars, etc., showing soil preparation such as plowing, harrowing, applying fertilizers, etc.

Class exercise.—Characteristics of potato soil: Rich, well cultivated, one that will conserve moisture and retain soluble fertilizer, a light sandy loam to be preferred to a heavy retentive soil. While excellent crops are frequently grown on heavy clay soils, the lighter soils will usually produce smoother, more even potatoes with bright skin and eyes of medium depth, and usually mature the crop at an earlier date.

1. Prepartion of the soil: Object of soil preparation—to provide for a rather weak root system, correct faults of local soil and climate, reduce the tillage after planting as much as possible.

2. Time of plowing—winter or fall plowing more desirable, especially where the soil does not run together and the slope is not steep enough to cause washing. This lessens the spring work and sometimes makes earlier planting possible.

3. Depth of plowing varies with the soil, usually from 8 to 12 inches unless subsoil is too near the surface.

4. Fertilizers: Object of fertilizing—potatoes require a complete fertilizer on most soils. Commercial fertilizers. Rotation. Green manuring. What objections to use of barnyard manure? When should lime be used? Methods of applying fertilizers to the potato crop.

Practical exercises.—Make a study of the types of soil in which potatoes are grown in the district. Which is most common? How

do the yields on the various types compare? Compare the quality of the potato crop raised on the different soils. How deep do the farmers of the district plow their potato soil? What is the common practice as to the time for plowing, fall or spring? What advantages can be found in either time of plowing? If the potato crop is one in a rotation, what is the usual practice in the district regarding fertilizers? If without a rotation, what is the practice? Note the farms that use green manure, that use stable manure, those that use commercial fertilizers, or a combination of fertilizers; and compare yields, both as to amount and to quality. Study the methods used by a successful potato grower of the district.

Correlations.—Correlations in language will be suggested by the various reports in practical exercises. Fertilizer costs, cost of plowing and otherwise preparing the land, will provide suitable correlations in arithmetic. In geography, a study of the commercial fertilizer as to source, manufacture, and shipping routes, will prove interesting and instructive.

LESSON IX.

Subject.—Planting potatoes including the treatment of seed.

Problem.—How should potatoes be prepared for planting, treated for disease, and when is the best time for planting?

Sources of information.—Farmers' Bulletins 386, 407, and 544; bulletins from State college of agriculture; textbooks in agriculture.

Illustrative material.—Specimens of diseased potatoes should be brought to the school and a comparison made between them and potatoes free from disease. Potatoes properly cut should also form a part of the illustrative material. The formula for treating potatoes should be placed on a chart in the room. Secure a small amount of formalin, and with the assistance of the class prepare some of the solution of the right strength for treating potatoes.

Class exercise.—Discuss the following topics:

1. Preparation for planting.—Treating the seed, purpose, diseases that may be treated, solutions used, method, results, cutting the seed, and principles involved which follow:

(*a*) Seed pieces should be blocky in shape to make surfaces as small as possible.

(*b*) The probability in most cases that the seed and eyes are more vigorous makes it better to cut each tuber in such shaped pieces that it will give the largest number having eyes from the seed end.

(*c*) To make sure of one good eye on every seed piece, it is well to have two wherever possible.

(*d*) The average weight of the seed must be adjusted to the needs of the crop for the soil planted—method of cutting, cutting racks, value of whole seed compared with cut seed.

2. A practice more or less common in Europe and one which is used to some extent in the United States is that of greening seed. Essentially it consists in keeping the seed during winter and spring in shallow trays racked up in buildings so constructed that each tuber is in the light. The sprouts at the seed ends start and grow short, green, and stubby. When planted, these potatoes start quickly and grow rapidly. The cost of the equipment and of the labor required to place the seed in the racks and again to place the seed in the ground with the sprouts up would be heavy in the United States. Unless seed which has been sprouted in this way for some time is planted with the sprouts up, there is trouble in loss of stand. However, a modification of the plan may be used for American conditions of cost and labor such that green sprouts grown in the light for a short time will not be broken off in a potato planter, and will give no trouble about coming up. Therefore the seed may be kept on the barn floor in the sun for two weeks or less and save the strength of the sprouts which would be lost by growth in the cellar.

For potato growers who desire to get their potatoes on an early market, a saving from one week to ten days may be made by this process.

3. Planting the crop—Time of planting depends upon the local soil, climate, and the market for which the crop is grown. Discuss advantages of early and late plantings; compare methods of ridging and level culture. Upon what does the value of each method depend? Methods of planting hill and drill—advantages and disadvantages of each; depth of planting and distance apart of plants and rows; planting tools; where would machinery for planting be economical? Discuss hand planting; depth of planting.

Practical exercises.—As a preliminary to the treatment of seed potatoes for diseases, some instruction on how to identify such diseases should be given. The student should be given an opportunity to sort potatoes, picking out those that show signs of disease. Practice should be given in preparing the formalin solution and in actually treating the seed potatoes. One pint of formalin (a 40 per cent solution of formaldehyde) diluted in 30 gallons of water is sufficient to treat 20 bushels of seed. Soak the potatoes about two hours. Actual practice in the cutting of potatoes should be given. If possible, take the class to a farm where potatoes are being planted, and with the consent of the owner, have them take part in the various planting processes from cutting the potatoes, to dropping and covering. Those students who have a potato project may obtain the practice work on their own plats, or may assist their fathers in planting. In such cases a report of the process should be made to the class. Where the potato scab is found, observations should be taken,

comparisons made between the yield with treated seed and with nontreated seed, both as to quality and quantity.

Correlations.—Problems in arithmetic growing out of comparisons between yields of treated and nontreated seed, together with cost of production in either case, including cost of treating compared with increase in yield, will be found valuable.

Written reports on treating seed potatoes and of the planting processes will afford language material.

LESSON X.

Subject.—Cultivation—first. Later.

Problem.—To study the correct methods of potato crop cultivation in order that the maximum yield may be secured.

Sources of information.—Farmers' Bulletin 365 (5 cents), 386 (5 cents), 407, and bulletins from State agricultural college.

Illustrative material.—Clip from farm papers pictures showing cultivation of potatoes; pictures of various kinds of cultivators and tools for tillage. If possible, have some of these cultivators brought to school where they may be examined. Visit a farm and see these tools in actual operation.

Class exercise.—The following principles in potato cultivation are noted and should be discussed as a basis for the practice work in growing potatoes:

Early cultivation:

1. Is it safe to assert that the major part of the cultivation of the potato crop should be done before planting.
2. Poor cultivation often the cause of poor yields.
3. Before potatoes are up, the field should be blind cultivated with a spike-toothed harrow or weeder.
4. Weeds should be destroyed and ground mulched.
5. After potatoes are up, deeper cultivation should be practiced, depth up to 8 to 10 inches, depending upon soil and locality.
6. Usually level cultivation brings better results than hilling. (Under what circumstances is ridging the better practice?)
7. The frequency of early cultivation depends largely upon the character of the season.
8. The things to be accomplished: Keeping down the weeds and conserving moisture.

Later cultivation:

1. Depth, shallow; form, level; ridge slightly after tubers are formed to prevent sunburn.
2. How long kept up should be determined largely by the season and condition of crop. As long as plants are green they are producing tubers.

3. Types of cultivators: Weeder, disk cultivator, corn cultivator, two-horse cultivator for large fields.

Cautions:

1. Careless tillage may work great injury upon the crop, as potato plants are more tender than weeds.

2. In using weeder or tooth harrow great care must be taken to prevent the teeth from injuring the sprouts.

3. In later growth the roots are in danger from too deep or too close cultivation. The greatest development of the roots in the plowed area is from 5 to 10 inches below the surface.

4. The danger of injury to the potato plant is greatest at blossoming time, when the exhausting effects of blossoming and forming tubers at the same time are very heavy.

Practical exercises.—This lesson should essentially be a guide to proper practice in potato cultivation. Many of the pupils will have potatoes as a home project, others will assist in the home work on the farm where potatoes are raised. The principles laid down in this lesson should be put into careful practice in either case.

A field trip to a potato farm would be valuable to the class. If the projects are under the supervision of the school, the teacher should try to visit each home as soon as possible to observe the progress of the projects. If the teacher is working in cooperation with the county or State club leader, it will be especially helpful to make these visits at the same time the official representative makes his visits to the work. In all cases this cooperation should strengthen the school work if it is well carried out.

Correlations.—The written reports, summaries, and costs of production as completed in the project work will furnish ample correlations in language and arithmetic. In case there is no project, the same reports on the work of the pupil on the home farm will furnish the same material.

LESSON XI.

Subject.—Potato-crop pests—Insects and diseases, how to combat them.

Problem.—To learn to identify the chief potato insect pests and diseases and to discover proper methods of control.

Sources of information.—Farmers' Bulletins 544, 557, and 868; bulletins from State college of agriculture.

Illustrative material.—Spraying charts. Illustrations of spraying apparatus. Samples of sprayers may often be borrowed from a farmer in the district or loaned by the local dealer. Samples of fungicides and insecticides. Illustrations or exhibits of the pests to be controlled. Samples of potato plants affected with the common fungus diseases may be brought to class for a study of the characteristics of the disease.

Class exercise.—The following topics are suggested as the basis of the class-room discussion:

A. Fundamentals of control:

Thorough spraying, clean cultivation, destruction of rubbish, and rotation of crops. Since there is a similarity in general methods, control of insects and diseases may be considered together.

B. Insect pests:

Insects damaging the potato crop may be classified as follows: (1) Insects chewing the leaves; (2) insects sucking the leaves and tips; (3) stalk borers; (4) insects affecting the tubers.

The following may be considered the chief insect pests of the potato plant:

Colorado potato beetle—Eats the leaves; controlled by spraying with arsenate of lead or Paris green.

Blister beetles—Leaf eaters; controlled same as Colorado beetles.

Potato flea-beetles—Leaf eaters; harder to control; spray with Bordeaux and arsenate of lead as probably the best means of control.

Leafhopper and plant-lice—Suck the leaves and tips; control by spray of nicotine sulphate or kerosene emulsion.

Potato-stalk weevil—Bores into the stalk; burn all infested vines; clear ground and burn all old stalks; destroy all related weeds; rotate crops.

White grubs (the larvæ of May beetles or June bugs)—Commonly known as "grubworms;" control by fall plowing and turn soil again in spring; rotation of crops.

C. Potato diseases:

1. Common diseases affecting the skin of the tuber:
   - (*a*) Common scab—Control; treat seed, rotation of crops.
   - (*b*) Russet scab—Control; treat seed, change of soil, deep preparation and cultivation.
   - (*c*) Powdery scab—Control; treat seed.
   - (*d*) Late blight dry-rot—Control; Bordeaux for blight, careful sorting and storing of the tubers.
   - (*e*) Powdery dry-rot—Control; care in handling; sorting out of injured potatoes.
   - (*f*) Eelworm—Control; careful selection.
2. Diseases of stem and leaves:
   - (*a*) Blackleg—Control; selected seed, formaldehyde treatment.
   - (*b*) Fusarium wilt—Control; rotation and sanitation.
   - (*c*) Bacterial wilt—Control; clean seed, sanitation.
   - (*d*) Early blight—Control; Bordeaux spray.
   - (*e*) Late blight—Control; Bordeaux spray.
   - (*f*) Rhizoctoniose—Control; clean seed, formaldehyde treatments, rotation.
   - (*g*) Tipburn—Control; in a measure, by Bordeaux, thorough cultivation.

D. Summary of control measures:

1. Results of seed selection; results in eliminating wilts, blackleg, eelworm, and other diseases which show on vines.
2. Results of seed treatment and rotation; reduce injury from Rhizoctoniose, scab, and blackleg, give clean seed.
3. Results of spraying; prevents early and late blight, prevents the blight rot, reduces injury from tipburn, repels flea beetles, kills most of the other insect pests, stimulates the vines to longer growth, gives increased yields.

E. Notes on spraying:

1. It pays to spray. It is economical to use a combination spray, a poison and Bordeaux.
2. Application should be timely and thorough; all the vines need to be well covered.
3. Do not wait until the plant disease begins to show among the vines. Anticipate its coming and spray before it arrives.
4. Do the work in season. Do not wait until it is too late. Once the blight gets a start in the potato field, it is very difficult to control.
5. Do not buy too cheap a machine. Get a good one and save time, trouble, and expense.
6. Be sure that the material is properly prepared.

Practical exercises.—This lesson should be made essentially a lesson of practice. Whenever practical, specimens of the insect pests should be brought to the class and identified. The treatment for such should be understood. In a like manner specimens of diseased potato plants and tubers should be studied. Pupils should be taught at least to identify the blights and scabs. The methods for control of each should be discussed carefully. Since the Bordeaux mixture for diseases and the arsenic poison for insects are the common sprays, the advantage of the combination spray should be shown. Actual practice work in preparation of these sprays and in their application should be given. Visit a potato farm and observe the spraying methods. If deemed practical, allow the class to assist in the spraying. By using borrowed sprayers and water in place of spray solution, actual practice may be given the class in the handling of sprayers and in the method of applying the spray. Instruct the class to be on the outlook for signs of potato diseases and insect pests, and have same reported to the class and a study made at once. To summarize: Give plenty of practice in identification of insect pests and diseases, practice in preparation and use of sprays, and drill in the general control methods outside of spraying. If any one of the students has a potato project, he can apply the principles of this lesson to his own crop.

Correlations.—Spraying costs compared with additional yield and losses incurred where no spraying is done; comparative cost of spraying with other costs of production will give practice work in arithmetic. The formulas for spray mixtures will also give additional practice.

Reports on observations and practice work will give language material and the preparation of spray charts and formulas will afford work in drawing.

LESSON XII.

Subject.—Uses of the potato—The potato as a food.

Problem.—To study composition, food value, and uses of the potato.

Sources of information.—Farmers' Bulletin 295; Office of the Secretary Circular 106; Department Bulletin 468; bulletins from State college of agriculture.

Illustrative material.—Construct a chart showing the composition of the potato; another showing the food value of the potato when compared with other foods. Samples of potato starch, alcohol, potato flour, and other products obtained from the potato.

Class exercises.—The following topics are suggested for attention in this lesson:

1. Composition of the potato—Water, starch, protein, crude fiber, fat, ash. Use iodin test for starch; use nitric acid and ammonia test for protein. Put a bit of potato on a piece of paper and put it into the oven or on top of a stove which is not hot enough to burn the paper. After heating hold paper up to light and see whether you can note any evidence of fat.

2. Uses of the potato—Potato starch, industrial alcohol, potato flour, glucose, sirup, mucilage, stock feed, and human food. Study briefly the minor uses mentioned above and the methods of making the products. Primarily, the chief attention should be given to the use of the potato as a human food.

3. The potato as a human food—(*a*) Food values, chiefly a starch food, but contains some protein and mineral matter.

(*b*) Advantages as a food—Furnishes an abundant supply of nutrients at a relatively low price; supplies nutrients in an easily digestible form; adds bulk to the food eaten.

(*c*) Textures of flesh in cooked potato—Soggy, usually rather low in starch and relatively high in protein; waxy, a greater proportion of starch to protein; mealy, starch content high, protein relatively low.

(*d*) Place in the general diet—Potatoes represent 3.9 per cent of the total cost of food, furnish 5.3 per cent of the total calories, 4.2 per cent of the total protein, 8.7 per cent of the total phosphorus, and 13.5 per cent of the total iron. Since phosphorus and iron compounds are as important to include in the dietary as protein and fuel foods, it is seen that for the small percentage of money expended for potatoes a generous supply of nutrients is obtained.

(*e*) Cooking—(1) Effects of cooking; transforms water into steam, expanding breaks down starch cells and free starch grains, coagulates the protein, affects minerals only slightly. Baking and steaming from all points of view are the best methods of cooking potatoes. (2) Losses in cooking; in paring, both by cutting away valuable material and exposing the soluble substances to the action of the water; in exposing a large amount of surface to the water; in soaking before cooking; in the use of cold water at the beginning of the cooking. (3) Recipes for using potatoes. Here a number of

well-tested methods for preparing potatoes for the table should be given and demonstrated.

Practical exercises.—In studying the composition of the potato, the pupils may make the tests themselves. (Caution: Be careful in handling the nitric acid.) Demonstrations in the methods of cooking potatoes may be made in the classroom. Recipes may be given out and the actual preparation may be done at home. If school lunches are served, the potato may form one of the foods served. Potatoes as a substitute for flour in various dishes may be demonstrated. The demonstrations at school should be followed up with the preparation of the same recipes at the home of the student.

Correlations.—Construct charts for the classroom showing the structure and the composition of the potato with relative amounts of each constituent.

Neat copies of recipes, reports on cooking processes, and a write-up of the study of the composition of the potato will give practice work in language, while a booklet on the uses of the potato well written, carefully prepared, and illustrated, if possible, will give correlation both in language and drawing.

Problems showing comparative cost of potatoes as a source of starch food with other starchy foods, and like comparisons as to supply of minerals, will afford practice work in arithmetic.

SUPPLEMENT.

Formula for Treatment of Seed Potatoes.

1. One pound 40 per cent formaldehyde to 30 gallons of water. Soak tubers for 2 hours. May be used over and over again for at least 10 times.

2. Four ounces dry corrosive sublimate to 30 gallons of water. Dissolve the powder first in a quart of warm water and then add it to the other. This solution should not come in contact with metal. Should not be used more than three times unless renewed. Soak potatoes for at least 1½ hours. Handle with great care, for this solution is very poisonous.

BORDEAUX MIXTURE.

Five pounds copper sulphate (blue vitriol).
Five pounds stone lime.
Fifty gallons of water.
Dissolve the copper sulphate in water.

Slake the lime with water. Then mix in a barrel containing 50 gallons of water. If desired, a 3.3 : 50 solution may be made, but the above is better. If used to any extent, slake solutions of both the copper sulphate and lime should be prepared and then added to the water when ready to use.

If desired to kill potato beetles or other insects, add to the Bordeaux mixture from 3 to 5 pounds of arsenate of lead or 1 pound of Paris green, and add 2 pounds of quicklime to prevent burning. One pound of Paris green to the acre either in water or Bordeaux mixture is ordinarily recommended. Arsenate of lead has the advantage of adhering to the vines and is only slightly washed off by the rains.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 785

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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THE FIELD TESTING OF COPPER-SPRAY COATINGS.

By J. R. Winston, *Assistant Pathologist*, and H. R. Fulton, *Pathologist, Office of Fruit-Disease Investigations*.[1]

CONTENTS.

THE PERSISTENCE OF SPRAYS CONTAINING COPPER.

General experience in the use of copper-containing spray mixtures indicates a progressive decrease in the fungicidal effectiveness of the spray coatings which is to a large extent proportional to the relative amounts of spray residue present. A direct decrease in effectiveness is brought about by weathering factors, such as washing by rain or dew, mechanical abrasion by wind, and slow chemical change in the exposed spray coating. An indirect decrease in effectiveness may result from the growth extension of plant parts, either through enlargement of organs already sprayed or through the development of new organs subsequent to the spray application. In practice the interval between spray applications depends on the rates of both weathering and growth extension. The second can be judged by careful observation. In so far as the first is concerned, observations are often misleading. Present-day spray calendars are based only in a general way on the average practical and experimental experience of past years. In any particular season or section or planting the actual requirements for adequate protection may vary widely from such average, necessitating greater or less frequency of applica-

[1] The writers wish to express their appreciation of the cooperation in connection with this work of the staff of the Miscellaneous Division, Bureau of Chemistry, United States Department of Agriculture.

tion than the standard spray calendar provides. It is difficult to estimate the effects of the complicated set of local factors that determine the effective period of any spray application. A suitable chemical test of the spray coating would seem to be a desirable aid in forming judgment as to the proper time for renewal. Such test should be simple, rapid, and reasonably accurate. The more refined methods of chemical analysis, while very exact, would not well serve the practical purpose, because of the special requirements in professional training, apparatus, and time.

A PRACTICAL METHOD OF FIELD TESTING.

The following method has been used during two seasons and has been found to be reasonably satisfactory in field practice. This is indicated by the consistent results obtained with varying strengths of copper sprays, many of which have been checked by exact chemical analyses of duplicate samples.

A 200-gram fresh weight sample of leaves is washed at least three minutes, with occasional stirring, in 1,000 c. c. of a 0.2 per cent solution of chemically pure nitric acid in water, either distilled or sufficiently pure to give correct results. A convenient amount of this acidulated wash water is treated with a few drops of 2 per cent solution of potassium-ferrocyanid solution, sufficient to precipitate the copper. A color comparison is then made with a series of known dilutions of a standard copper solution, similarly treated with the potassium-ferrocyanid solution. From this comparison the copper content of the wash water is determined. For more exact readings a colorimeter may be used.

The standard copper solution is made by dissolving 3.928 grams of pure crystals of copper sulphate in water to make 1,000 c. c. Each cubic centimeter of such standard solution would then contain 1 milligram of copper, and by proper dilution with water stock solutions may be readily prepared for the comparison series containing one-half to 10 mg. of copper per 100 c. c. of water, in one-half or 1 mg. grades. If the wash water gives readings above 8 or 10 mg. of copper per 100 c. c. it should be diluted for accurate color comparison and account of this taken in figuring results. On the basis indicated above, any direct reading multiplied by 5 will express the amount of copper in the spray residue in milligrams per 100 grams fresh weight of leaves, a convenient unit for tabulation purposes. The solutions of potassium ferrocyanid and of nitric acid may be varied in strength for considerable differences in the copper content of the spray coating, so as to avoid using unnecessarily strong solutions, with consequent reduction in the delicacy of the test. There must always be a sufficient amount of nitric acid to dissolve completely the copper compounds and of potassium ferrocyanid to precipitate them completely.

Due care must be taken to make the leaf samples representative. About three samples of 200 grams each should be taken at various parts of a sprayed planting. Under ordinary conditions collections every three or four days will give satisfactory indication of the persistence of the spray residue. If in the case of any variety of leaf there is a tendency toward discoloration of the wash water from dissolution of organic compounds in such a way as to interfere seriously with the color comparisons, one may titrate a measured quantity of the wash water with a solution of potassium ferrocyanid previously standardized against a copper solution of known strength, using a weak ferric-chlorid solution as the end-point indicator, in small drops on a white porcelain plate. Tests on many kinds of crop plants indicate that this titration method will be seldom needed. Permitting the weighed leaves to dry or to "heat" may interfere with accurate testing.

The coating on the foliage will usually prove to be a fair index to the thoroughness of application to other parts. For convenience, the samples are based on weight, but the spray coating is proportional to area. The different ratios between these, due to difference in species or age of leaves, when considerable, should be given due weight in making comparisons. Obviously, it is possible to secure as high tests from strong sprays unevenly applied as from moderate strengths more evenly and effectively used, but it is believed that the histories of such cases will guard against incorrect interpretations.

The amount of spray residue necessary for adequate protection against any specific disease would doubtless vary with a complex set of factors. There would thus exist a critical transition zone with maximum and minimum limits above which protection would be secured and below which protection would be insufficient. These limits can be determined only from investigations covering a period of years. The best spray practice should aim at keeping the spray coating always above the maximum limit, and ordinarily good practice should never take the risk of falling below the minimum limit.

FIELD TRIALS.

During the two seasons that this method has been in use, something like 75 schedules have been tested by the writers. The following results are selected as being representative.

APPLE LEAVES AT CROZET, VA.

Winesap apple leaves were tested at Crozet, Va., June 23 to July 22, 1917. The orchard was about 5 acres in extent and was sprayed with 3–4–50 Bordeaux mixture on the date of the first collection. Each sample was divided, one portion being sent to the Bureau of Chemistry, United States Department of Agriculture, for exact analysis, and the other tested by the field method outlined above.

The analytical data are based on the dry weight of the samples, and the field tests data have been converted to the same basis by assuming a constant value of 35 per cent for the dry weight of the leaves (fig. 1).

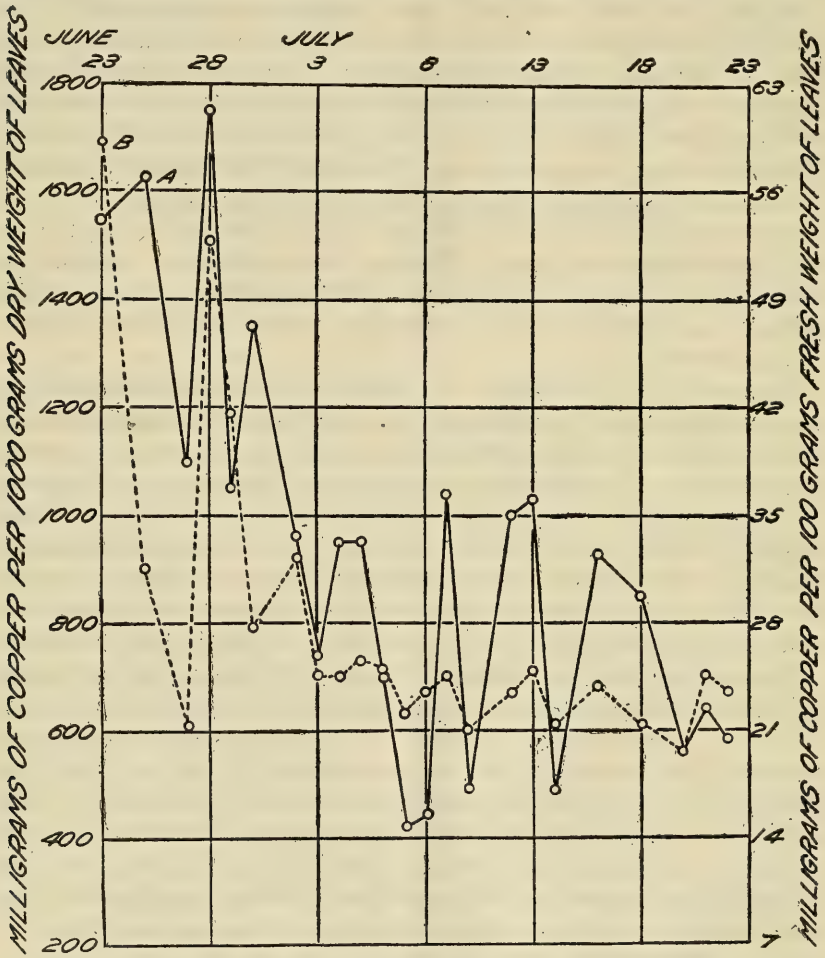

FIG. 1.—Tests for copper on apple leaves sprayed with 3-4-50 Bordeaux mixture. *A* represents the results of chemical analyses on the basis of milligrams per 1,000 grams dry weight of leaves. *B* represents the results of field tests of duplicate samples on the basis of milligrams per 100 grams fresh weight of leaves. The two scales are plotted on an equivalent basis, assuming the dry weight of the leaves to be constantly 35 per cent.

A scale for equivalent readings in milligrams of copper per 100 grams fresh weight of leaves is also indicated in the figure.

At this early period in the work the samples were too small to give the best results for so large a planting. However, there is reasonably close agreement between the graphs secured by the two methods, with the exception of a few of the first determinations.

Tests were made during July and August, 1917, in two apple orchards, A and B, at Crozet Va., sprayed by the owners with 3-4-50 Bordeaux mixture according to their usual practices. Both orchards

had received a first application of the mixture about the middle of June. The readings indicate the milligrams of copper per 100 grams fresh weight of leaves. Two other orchards, C and D, in the same locality, bore light crops of fruit and for this reason were given rather light spraying of 3–4–50 Bordeaux mixture by their owners.

Tests before and after the second and third spray applications in these orchards gave the results shown in Table I.

TABLE I.—*Field tests in spraying apple orchards A, B, C, and D with 3–4–50 Bordeaux mixture, at Crozet, Va., in July and August, 1917.*

Spray application.	Orchard A.		Orchard B.		Orchard C.		Orchard D.	
	Date sampled.	Reading.	Date sampled.	Reading.	Date sampled.	Reading.	Date sampled.	Reading.
		Milligrams.		*Milligrams.*		*Milligrams.*		*Milligrams.*
First	July 9	41.6	July 9	35.7	July 19	41.6	July 20	29.4
	July 12	29.4	July 12	21.7	.....	.....	.....	.....
Second	July 17	125	.....	.....	July 23	62.5	July 24	47.6
	July 19	125	July 20	166.6	July 26	20	July 26	31
	July 23	111.1	July 24	125	.....	.....	.....	.....
	July 26	76.9	July 26	100	.....	.....	.....	.....
Third	August 2	100	Aug. 2	125	Aug. 3	55.5	Aug. 2	71.4

BEARING GRAPEFRUIT TREES AT WINTER PARK, FLA.

Two spray applications on a commercial basis were made on plats of bearing grapefruit trees at Winter Park, Fla., the first on March 9 and the second on April 16, 1918, using a power sprayer developing approximately 225 pounds pressure. The plats contained 30 trees each.

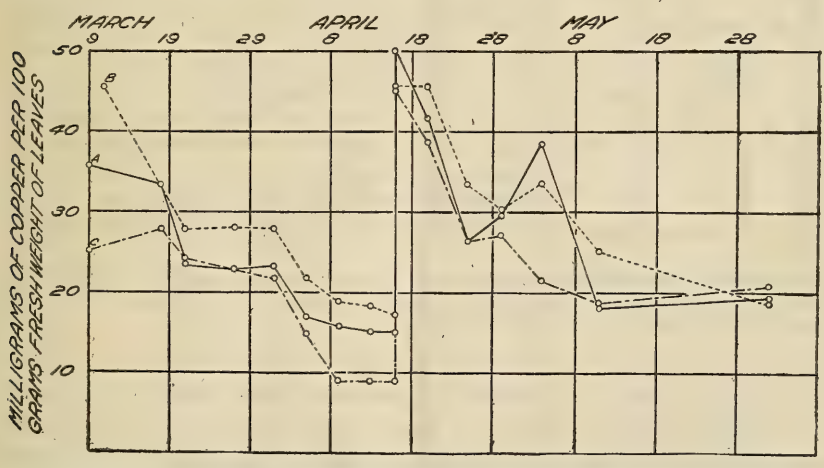

FIG. 2.—Field tests for copper on grapefruit leaves sprayed with 3–4–50 Bordeaux mixture (*A*), 3–4–50 Bordeaux mixture with the addition of a certain oil emulsion (*B*), 3–3½–50 Burgundy mixture (*C*). Each application was renewed on April 17.

Single samples of 200 grams fresh weight were taken from each plat at intervals of about four days until June 1 (fig. 2). In this test 3–4–50 Bordeaux mixture was used with and without a certain oil

emulsion, and the Burgundy mixture was also made up with 3 pounds of bluestone. The tests show consistent decreases in copper content of the coatings.

CITRUS NURSERY STOCK AT BRADENTOWN, FLA.

At Bradentown, Fla., comparative tests were made with three strengths of Bordeaux mixture, made up according to 3–4–50, 2–2⅔–50, and 1–1⅓–50 formulas. The applications were made in

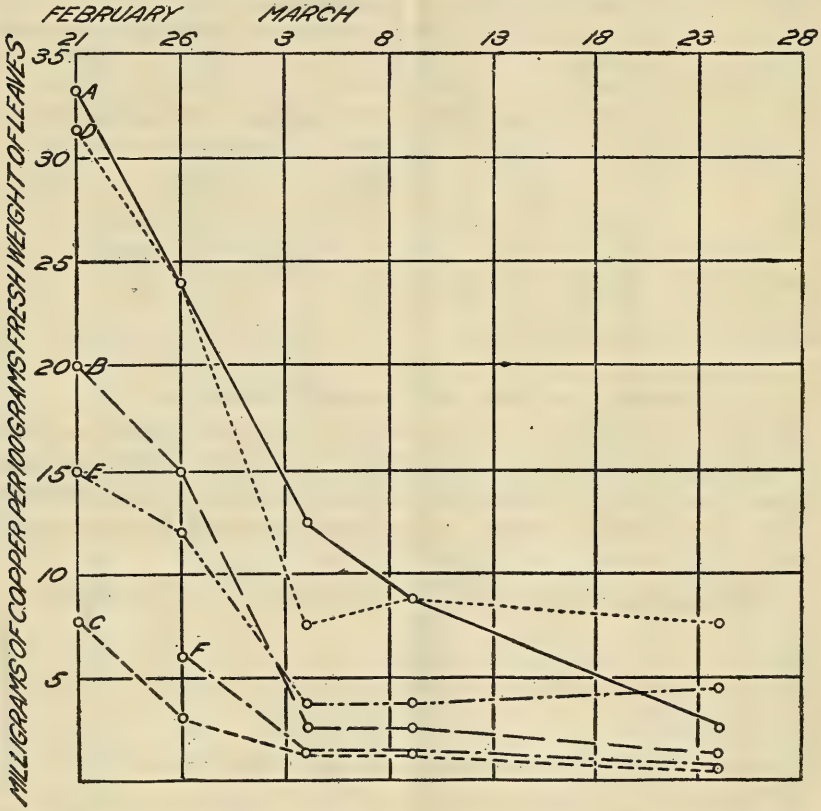

FIG. 3.—Field tests for copper on sour-orange leaves. *A* and *D* were sprayed with 3–4–50 Bordeaux mixture; *B* and *E*, with 2–2⅔–50 Bordeaux mixture; and *C* and *F*, with 1–1⅓–50 Bordeaux mixture. *A*, *B*, and *C* were in Nursery I; *D*, *E*, and *F* in Nursery II.

February and March, 1918, on two nursery plantings of overgrown sour-orange stock. In Nursery I the trees were about 6 feet high; in Nursery II about 3 feet. A bucket spray pump was used, and in each nursery measured amounts of spray were applied to equal lengths of the nursery rows to secure a distribution of the spray as equal as possible. The fresh weight of each leaf sample approximated 100 grams. Figure 3 shows the relative agreement of the field test results with the strengths of spray applied. Plat F was sprayed with the others on February 21, but the first sample was lost.

CELERY AT BRADENTOWN, FLA.

Figure 4 shows the behavior of Bordeaux mixture on celery at Bradentown, Fla., in February and March, 1918. Each grower prepared and applied the mixture in his own way to plantings of

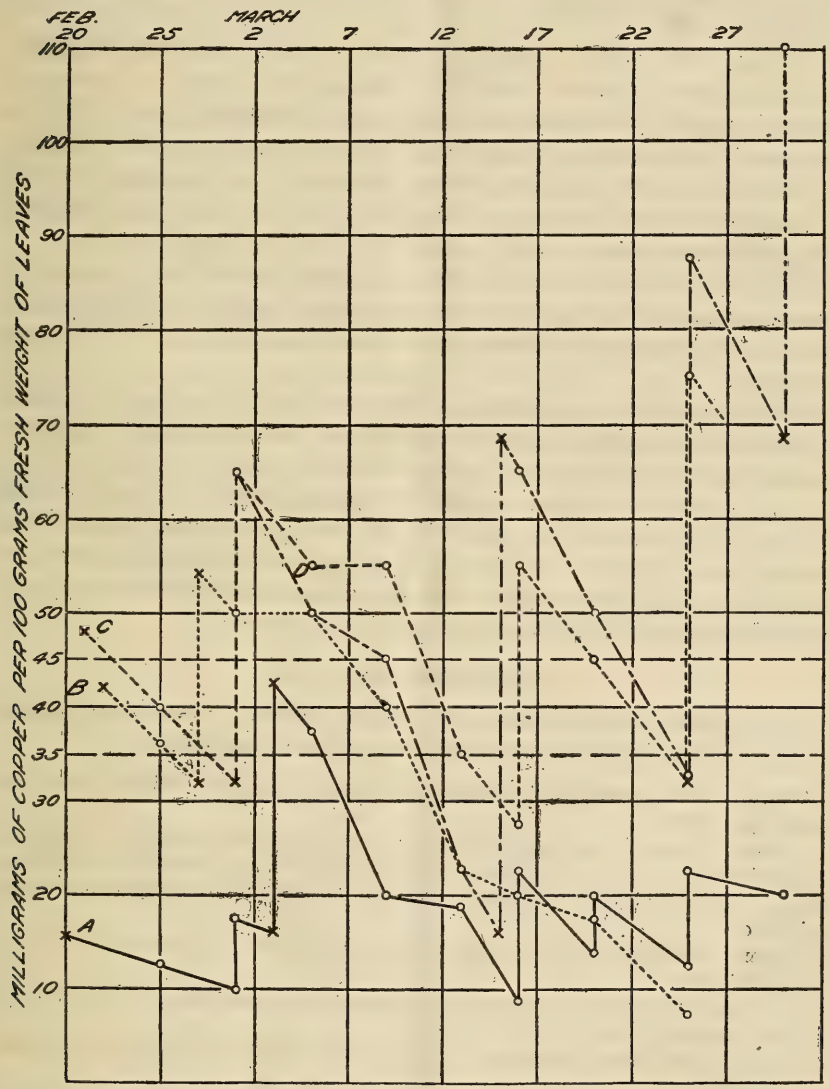

FIG. 4.—Field tests for copper on celery leaves. Four fields were sprayed by the owners with Bordeaux mixture supposedly made up in each case with 6 pounds of bluestone in 50 gallons. A hypothetical safety zone is indicated between the 35 and 45 milligram tests. The actual determinations are indicated by O, the estimated interpolations by X.

1 or more acres. In every case the grower claimed that 6 pounds of bluestone were used in 50 gallons of the Bordeaux mixture. Knapsack sprayers were used. With the exception of field D one or

more applications had been made before testing began. When samples could not be taken immediately before and after a spray application, estimates have been made from the previous or subsequent direction of the graph to determine the probable values, and such approximations are indicated by X rather than by O in plotting.

The owner of field A, besides guessing at the quantities of ingredients, followed a faulty method of mixing the spray. In spite of frequent applications, the results were very unsatisfactory. If it is assumed that adequate protection from some specific celery disease is secured by spray residues testing between 35 as a minimum and 45 as a maximum for a transition zone, it will be seen that this field was really protected for only 3 out of 38 days by 6 applications.

Field B, with two applications, dropped below this theoretical transition zone 10 days after the second application and stood with insufficient protection during the remaining 15 days of the test period.

Field C, with four applications, was insufficiently protected during a total of five days, but this could have been prevented by slight shortening of the intervals between applications.

Field D was late celery sprayed first on March 1. On the basis of the limits assumed for the critical zone, the second application should have followed the first in 10 days, and the interval between the third and fourth might have been considerably prolonged provided large growth development had not occurred.

DIRECTIONS FOR USE.

As a guide in the practical use of this method, a condensed statement of the successive steps may be outlined, as follows:

Dissolve 3.928 grams of pure crystals of copper sulphate in distilled water and make up to 1,000 c. c.

Prepare in well-stoppered bottles stock dilutions of the above solution containing one-half c. c., 1 c. c., 1½ c. c., 2 c. c., and so on up to 10 c. c., in 100 c. c. of distilled water. These dilutions would then contain from one-half to 10 milligrams of copper per 100 c. c.

Prepare a weak solution of potassium ferrocyanid, about 2 grams in 100 c. c. of distilled water.

All of the above may be prepared in advance, by a pharmacist if desirable, and kept for a season's use.

Collect at least three representative samples of sprayed leaves, each of 200 grams fresh weight.

Wash each sample separately in 1,000 c. c. of pure water to which has been added 2 c. c. of chemically pure nitric acid, being careful to use glass or chinaware vessels and stirring occasionally for at least three minutes.

Pour into test tubes or vials of uniform size about 5 c. c. portions of the graded stock solutions of copper sulphate, and add to each a few drops of the potassium-ferrocyanid solution, sufficient to develop the maximum color reaction.

Treat similarly 5 c. c. portions of the washings from the leaf samples. Compare the color developed in these with the graded series. Take for a reading the number expressing milligrams of copper per 100 c. c. in the stock dilution that matches closest in color intensity. Simply multiplying this reading by 5 will then give a value in milligrams of copper per 100 grams fresh weight of leaf sample, a convenient unit for finally expressing the amount of copper in the spray coating. The results from the several samples may be compared and averaged.

CONCLUSION.

This field method of following the persistence of copper-containing sprays promises to be of service to pathological investigators, agricultural experts, and commercial growers along these lines: (1) To secure data showing the persistence of copper-containing sprays as it may be influenced by method of preparation, weathering, or other factors; (2) to determine the minimum and maximum limits of working safety zones, as measured by evenly distributed residues, effective for the practical control of specific diseases; (3) to secure prompt correction of faulty spraying practices, either in the preparation of mixtures or in the times or modes of application, with a view to insuring more effective and economical protection of crops; and (4) to serve as a practical guide in timing new applications, especially after rainy periods.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 786

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief

Washington, D. C. ▼ May 28, 1919

PREVAILING PLANS AND PRACTICES AMONG FARMERS' MUTUAL FIRE INSURANCE COMPANIES.

By V. N. Valgren,
Investigator in Agricultural Insurance.

CONTENTS.

INTRODUCTION.

There are about 1,950 farmers' mutual fire insurance companies in the United States. These companies have in general shown a high degree of stability and have proved of much value to their members. The total amount of insurance which they now have in force exceeds $6,000,000,000. A questionnaire was sent out by the Bureau of Markets making inquiry concerning the plans of organization and the business practices of these companies. The information contained in this bulletin is largely a summary of the replies to this questionnaire.

The organizations here classed as farmers' mutual fire insurance companies are those mutuals whose risks consist either entirely or very largely of farm property. In most States where these companies exist they are recognized as a separate and distinct class of insurance organization and operate under laws which practically

NOTE.—This bulletin should be of special interest to the directors and officers of farmers' mutual insurance companies, and to those who contemplate the organization of such companies.

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limit the insurance written by them to country risks. In several of the Eastern States and some of the Southern States, however, no such distinct class of farmers' mutuals has been provided for by statute. In these latter States, therefore, it is frequently difficult to determine which of the mutual fire insurance companies should be considered farmers' mutuals and which should not. No company has been included in the above or in succeeding figures whose reply indicated that the risks carried were other than farm property to an extent greater than 35 per cent.

Of the organizations complying with the above-mentioned requirements a total of 1,161 companies filled out the questionnaire.[1] The returns upon which the bulletin is based are thus approximately three-fifths complete and are believed to be sufficiently numerous and also sufficiently representative to enable one to draw fairly accurate conclusions concerning the prevailing plans and practices of the entire group of companies here considered. On many points, however, it will be noticed that the variations in plans and methods are quite as noticeable as any tendency toward uniformity.

LOCATION OF COMPANIES, DATE AND METHOD OF INCORPORATION.

Farmers' mutual fire insurance companies are found in greater or smaller numbers in all the States except Florida, Louisiana, New Mexico, Arizona, and Nevada. More than four-fifths of these companies, however, are located in the Middle Atlantic and the North Central States. Their number and approximate locations are indicated on the outline map shown on page 3.

For most of the States the date of organization of the insurance companies is given in the annual report of the insurance department. It is therefore possible to give a more complete statement concerning this phase of the question than information secured by means of the questionnaire alone would permit. Using both the questionnaire and the insurance reports, it has been possible to determine the date of organization of 1,879 of the farmers' mutual fire insurance companies. The number of existing companies which were organized during each decade is indicated in the following table:

	Companies.		Companies.
1820–1829	2	1870–1879	484
1830–1839	8	1880–1889	333
1840–1849	38	1890–1899	450
1850–1859	61	1900–1909	254
1860–1869	98	1910–1917	151

[1] The information thus secured has already been used as the basis for various conclusions in Yearbook Separate 697, and in Department Bulletin 530 (see appendix), but the data have not before been put in summary form suitable for general distribution.

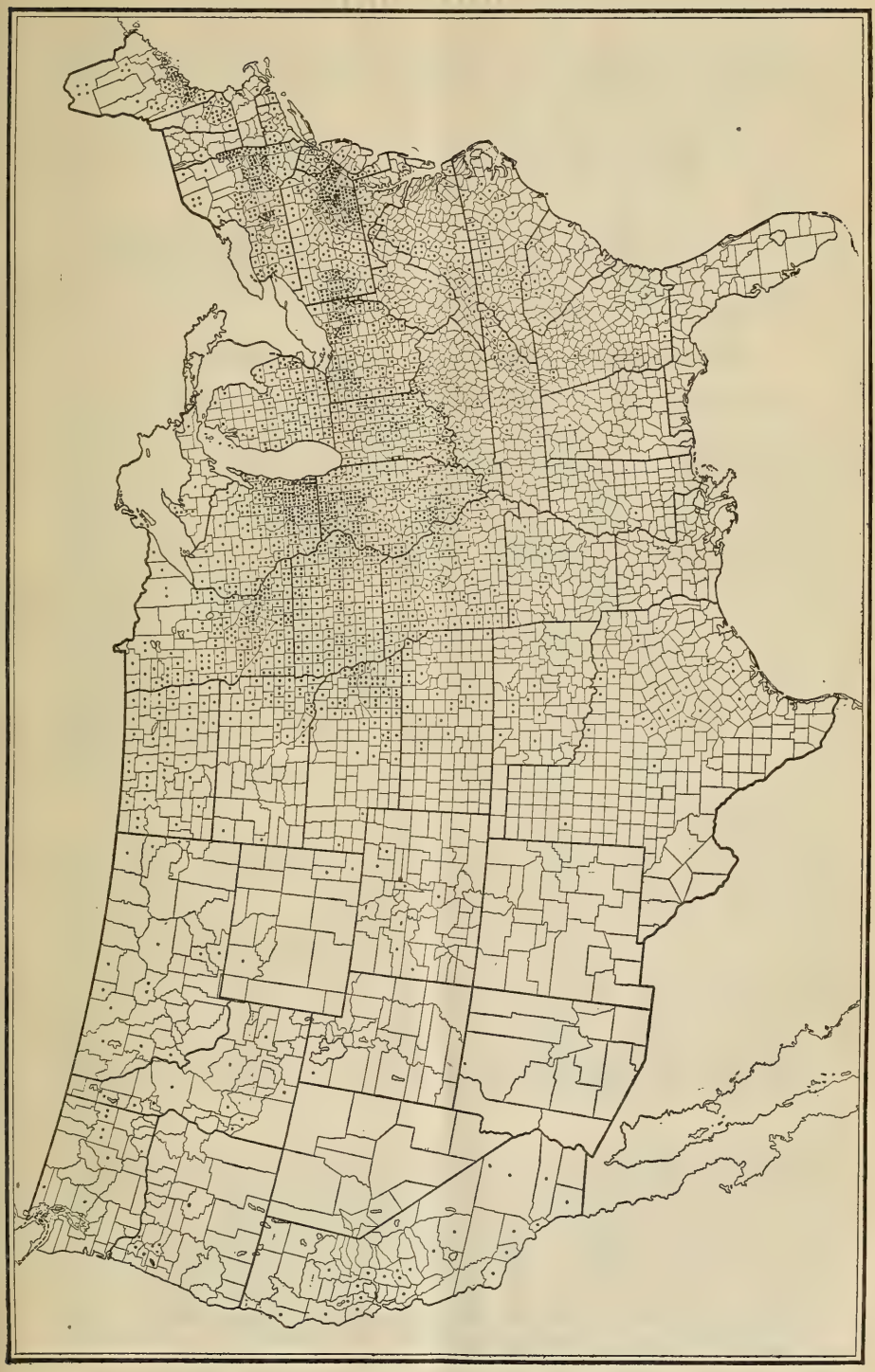

FIG. 1.—Farmers' mutual fire insurance companies. Each dot represents a company.

Of the 1,161 companies replying to the questionnaire 124 were incorporated by special acts of the legislatures, while 967 were incorporated under general statute. Twenty-one of the companies existed as voluntary associations without incorporation and 49 gave no information on this particular question.

Most of the companies incorporated by special charter are in the East and Southeast. The companies in the Middle West and the far West, on the other hand, are almost universally organized and operated under general statutes enacted specifically for farmers' mutuals. The unincorporated associations were almost entirely confined to Indiana and Missouri.

MEMBERSHIP, VOTES, AND ANNUAL MEETING.

One thousand one hundred sixteen companies reported the number of members. The smallest membership of any company was 25 and the largest was 32,433, the average membership for the 1,116 companies being 1,532. Twenty-eight companies had a membership of less than 100, while 313 had a membership of between 100 and 500, and 257 had a membership of between 500 and 1,000, making a total of 598 companies reporting, each of which had less than 1,000 members. The companies having less than 100 members were in general recent additions to the list of farmers' mutuals. Two hundred sixty-seven companies had a membership of between 1,000 and 2,000; 130, between 2,000 and 3,000; and 62, between 3,000 and 5,000; while 59 companies had 5,000 or more members. Nearly four-fifths of the 1,116 companies reporting membership, therefore, were organizations of less than 2,000 members.

Information concerning the voting privilege of members was given by 1,150 companies. Of these, 933 reported that each member had one vote, while 217 reported that plural votes based upon either the amount of insurance or the number of policies held by a given member were allowed. Of the 217 companies allowing plural votes, 179 used the amount of insurance and 38 used the number of policies held in determining the number of votes granted to a member. The prevailing plan, as the figures indicate, is to allow each member one vote regardless of amount of insurance or number of policies held. More than four-fifths of the companies followed this plan.

Concerning the date of the annual meeting, 1,144 companies gave information. Of these, 734 held the annual meeting in January, 82 in June, 75 in October, 63 in December, 44 in August, 34 in September, and 33 in May, while smaller numbers held such meeting during yet other months, the date in general being fixed at such time of the year as, for the locality in question, would make it most convenient for members to attend.

The number present at the last annual meeting was reported by 1,002 companies. The largest number present at the annual meeting of any one company was 1,350 and the smallest was 3. The average number reported was 61. In only 179 cases was the number present larger than 100, and in only 48 cases was it less than 10.

DIRECTORS AND OFFICERS.

The maximum number of directors of any one of the 1,140 companies reporting on this point was 55 and the minimum was 2. Only 91 companies reported more than 15 directors and only 66 companies reported less than 5. The average as well as the most common number of directors for the companies reporting was 9, and 405 companies actually reported this number for their organization.

The term for which directors are elected was reported by 1,144 companies. The term was one year in the case of 517 companies, two years in the case of 62 companies, three years in the case of 508 companies, four years in the case of 43 companies, and five years in the case of 11 companies. One company reported the term of directors as seven years; and 2 reported that the directors held their positions without any limitation as to term of office. It thus appears that the favorite term of directors is either one or three years. It may also be stated that in a number of the laws more recently enacted it is specifically prescribed that the term of directors shall be three years and that one-third of the number shall be elected each year.

Practically all the companies giving information reported having a president and a vice president. In the case of secretary and treasurer, 926 companies reported these offices as held by two distinct persons, while 226 companies reported a secretary-treasurer, indicating that the duties of secretary and treasurer in the latter group of companies were performed by the same person.

Of the 1,145 companies giving information concerning the term for which officers are elected, 1,032 gave one year; 47 companies gave two years; 53, three years; 11, four years; and 2, five years. In the case of officers, therefore, as distinguished from directors the practice of a one-year term is fairly uniform among the farmers' mutuals.

Besides directors and officers, 249 companies reported an auditing committee; 240 companies reported an executive committee; and 106 companies reported an adjusting committee. A few companies reported yet other committees under such titles as appraising, valuation, application, revision, inspection, cancellation, arbitration, appeals, finance, and advertising. A number of these terms refer, of course, to committees with identical or at any rate similar duties.

HAZARDS AND RISKS.

All the companies returning questionnaires gave information concerning the hazards against which insurance was written. Thirty-three companies insured against fire only and 958 against fire and lightning. One hundred and seventy companies reported giving so-called combined protection, covering fire, lightning, and windstorm in their contract.

Farmers' mutuals writing combined protection were found in nearly all States with the exception of those located in New England and on the Pacific coast. In the case of companies operating in all or the greater part of a State the offering of windstorm protection as well as of fire and lightning protection is a fairly common practice everywhere. This practice in so far as it relates to county or relatively local companies, however, is limited largely to the States of the South. In a number of the States of the Middle West special windstorm insurance companies doing a State-wide business and working in close cooperation with the local fire insurance mutuals have been developed. The plan of carrying windstorm insurance by a relatively local company has proved disastrous in a number of instances, the losses from a single severe storm in a community not infrequently exceeding all available resources of a small company. From the point of view of the fire hazard, on the other hand, so far as the typical farming community is concerned, each group of farm buildings and to a considerable extent each building in the group constitutes a separate and distinct risk, and hence nothing corresponding to a conflagration hazard is present. Considerable allowance may of course be made for differences in the probability of severe windstorms in different sections of the country, but experience has proved that few, if any sections are entirely exempt from the most destructive form of windstorm known, namely, the tornado.

All but four of the companies reporting gave information concerning the property insured. One thousand sixty-four companies reported insuring only farm property and similar segregated risks within the limits of cities or villages, while 93 companies reported insuring also a larger or smaller amount of other city property. Companies reporting more than 35 per cent of the insurance on their books as city property were, as already stated, not included in this summary.

Among the 898 companies which reported the maximum single risk accepted by them, the highest for any company was $15,000 and the lowest $750. A total of 349 companies reported their maximum single risk as larger than $4,000, and only 58 companies provided for a maximum of less than $2,000. The average of such maximum risk for these companies was $3,994. Two hundred sixty-three

reports gave no reply to this question. The significance of these figures, it should be pointed out, is materially lessened by the fact that the definition of a "single risk" or "any one risk" as used by these companies is by no means uniform, some companies applying the term to all the property insured on a given farm, or even in a few instances to the property covered by a single policy, while others use it in the more appropriate sense as signifying a unit or group of property subject to destruction by a single fire.

The highest percentage for which insurance is granted by any of these companies was reported as 100 per cent of the cash value and the lowest such maximum was 33 per cent. The average percentage fixed as a maximum for insurance granted was 70 per cent of the cash value. Only 41 companies reported accepting risks for more than 75 per cent, and only 14 companies reported the maximum percentage of value permitted to be insured as less than 66⅔.

The maximum term for which policies are issued was given by 1,155 companies, and of these, 806 gave 5 years as such maximum. Thirteen companies reported writing policies for not longer than 1 year; 58, for not longer than 3 years; 19, for not longer than 4 years; and 19 others, for not longer than 6 years. Thirteen companies reported writing policies for terms up to 7 years and 13 others for terms up to 10 years. Perpetual or annually renewable policies were written by 214 companies. It appears, therefore, that 5 years is the most common maximum period for which policies are issued by these companies, more than two-thirds of them reporting this term, while nearly one-fifth of the farmers' mutuals issue policies which remain in force as long as assessments are met by the insured or until the company finds reason to cancel the insurance.

BUSINESS TERRITORY.

Information concerning the territory to which they confine their operations, either as the result of legal restrictions or of self-imposed limitations was given by 1,145 companies. Of these, 386 companies reported their business territory on a township basis; 715, on a county basis; and 44, on a State basis. Of the so-called township companies, 87 operated in a single township; 38, in 2 townships; 21, in 3 townships; and 32, in 4 townships. Ninety-eight companies operated in from 5 to 9 townships; 40, in from 10 to 14 townships; 44, in from 15 to 24 townships; and 26, in 25 or more such units of area. The companies operating on a township basis are most common in Illinois, Wisconsin, and Minnesota, although a considerable number of such companies are also found in Maine, New Hampshire, New York, Pennsylvania, and Ohio.

Of the 715 companies reporting their business territory on a county basis and therefore frequently termed county companies,

373 operated in all or a part of a single county; 102 operated in 2 counties; 87, in 3 counties; and 44 in 4 counties. Eighty companies operated in from 5 to 9 counties; 17, in from 10 to 14 counties; 6, in from 15 to 24 counties; and 6 others in 25 counties or more.

Of the 44 companies reporting business territory on a State basis, 11 indicated that they operated in part of the State; 29 that they operated in an entire State; and 4, that they operated in two States.

A question was also asked concerning the maximum business territory permitted the company by the law or charter authorizing it to do business. From the replies to this question it appears that 811 companies operated in an area equal to the maximum permitted, while 317 companies restricted themselves to a smaller area than that legally permitted, and 9 companies on the other hand, operated in larger areas than those prescribed to them by law. Twenty-four companies did not give the necessary information for a comparison of this kind. It may be pointed out in this connection that some of the earliest farmers' mutual insurance laws limited the companies organized thereunder to a single township. There has been, however, a general tendency to increase the business territory permitted, and more recent laws almost invariably prescribe a maximum business territory on a county basis.

PLAN OF RAISING FUNDS AND FREQUENCY OF ASSESSMENTS.

Twenty-five of the 1,161 companies returning questionnaires reported doing business on a fixed premium plan, while 1,113 reported relying mainly or in part upon assessments for their funds with which to meet the obligations assumed. Twenty-three companies gave no information upon this point. Most of the companies operating essentially on the assessment plan collect in advance a membership or policy fee together with a slight advance charge based on the amount of insurance written. The policy or membership fee collected varied from $15 to 25 cents. The average such charge for all the companies reporting was $1.54. The $15 fee, a membership fee collected only once from each member, was charged by only a single company, the next highest membership or policy fee being $5. Only 17 companies reported such charges in excess of $3, and only 45 companies reported similar charges of less than $1. The initial charges based on the amount of insurance written varied from 50 cents per hundred per year to two-tenths of a cent per hundred per year, the average of such charges being approximately the equivalent of 6 cents per hundred per year for the term of the policy.

In reply to a question on frequency of assessments, 121 companies reported that no assessment had hitherto been made. Of the remaining companies 76 reported having made but 1 assessment during the

last five years, while 99 reported having made 2 assessments during the same period; 135 reported 3 assessments; 116, 4 assessments; 413, 5 assessments; 62, 6 assessments; 26, 7 assessments; 22, 8 assessments; and 21, 9 assessments. Thirty companies reported from 10 to 14 assessments, and 9 more than 15 assessments. The greatest number of such assessments levied by any one company during the last five years was 29. Thirty-one companies did not report the frequency of assessments. From the figures just given it may be seen that the most common plan is that of annual assessments, while in the remaining cases less frequent assessments than 1 per year are considerably more common than more than 1 assessment during the 12-month period. The plan of collecting in advance at least one year's estimated cost of insurance, and the assessing in advance for each of the succeeding years of the policy term, appears to be gaining in favor among these companies.

LIABILITY OF THE INSURED.

Of the companies reporting, 829 operated under the unlimited liability plan, the insured obligating himself to pay his pro rata share of all losses and expenses legally incurred by the company. Of the remaining companies, 215 reported limiting the liability of the insured to a specific amount, while 117 companies returning questionnaires gave no information covering this question. The average obligation assumed by the policyholder in the companies which reported limited liability was equal to $1.41 per hundred per year while the policy remained in force. A special note was required as evidence of the liability of the insured by 161 companies while the greater number reporting, namely, 872 companies, relied on a clause in the insurance contract for the validity of the obligation assumed by the insured. One hundred twenty-eight companies reporting did not give information upon this point. It would appear, therefore, that less than one-fifth of the farmers' mutuals limit the liability of the insured, and that even a smaller proportion require a premium note. The prevailing plan is that of unlimited liability, the obligation to pay his proper part of losses and expenses being assumed by the insured as a part of the insurance contract.

CLASSIFICATION OF PROPERTY.

The returns from 334 of the companies indicated that they made a more or less elaborate classification of the risks insured, while 733 companies stated specifically that no classification at all was made by them. The remaining 94 companies returning questionnaires did not answer the question concerning classification. It may be added that proper classification for premium and assessment purposes has

only recently begun to be considered seriously by these companies, and that a number of them have adopted a classification of their risks within the last year or two. This is especially true in the better developed rural sections of the country. Three main reasons may be given as to why the mutuals in these sections are adopting a classification of their risks. First, a demand for a closer approach to justice in the charges collected from the members, it being obviously unfair to apply the same rate of premiums or assessments to highly desirable risks as is applied to the more hazardous ones. To apply the same rate, for example, to a well-constructed stone or brick dwelling with slate or tile roof and provided with proper lightning protection, as is applied to an unrodded wooden barn, involves a very material discrimination against the better of the two risks. Secondly, it has been found that expediency as well as justice demands a reasonable classification of farm risks. Without such classification it is possible for a larger company that does classify or rate its risks, by means of a competitive offer, to take away from an all-one-rate local mutual the most desirable risks in its territory. This can be done, of course, even though the cost of insurance in the local mutual on its one and only class of property be much lower than the average cost on the same property in the larger competing company. Lastly, it has been found that the recognition of certain loss-resisting features by means of suitable concessions in the classification and rates applied is one of the most practical ways of encouraging the general improvement of the risks within the business territory of the company. A suggested classification of farm risks may be found in Department Bulletin 530 of the United States Department of Agriculture.

METHOD AND COST OF GETTING BUSINESS.

The question of who looks after the matter of soliciting business was answered by 1,141 companies. Three hundred sixteen companies stated that business was solicited by the directors only, 182 by officers only, and 82 by directors and officers, making a total of 580 companies soliciting business only through responsible officials of the organizations. Four hundred two companies reported solicitation by special agents only; 65 by directors and agents; 31 by officers and agents; and 16 by directors, officers, and agents. Forty-seven companies reported that no solicitation of business was done by any one, the company relying upon the initiative of those needing protection to apply for membership. Twenty companies returning questionnaires gave no information on the method of getting business.

Since it is known that in many cases certain directors or officers are specifically designated agents for the solicitation of business it is probable that many companies reported securing business through

special agents when as a matter of fact it would have been equally true to state that this service was performed by certain directors or officers. For this reason it is believed that the plan of securing business through responsible officials of the companies is even more common than the above figures would indicate. Many of the companies, it may be mentioned in this connection, pride themselves upon the fact that their history indicates a steady and healthy growth covering a number of decades and that every member of the company has been admitted as a result of a personal application on his part and without any effort or expense on the part of the company. While this passive attitude toward the growth of the company has worked exceedingly well in certain communities it is by no means universally applicable.

Only 232 companies reported making efforts to secure business through advertising, while 892 stated specifically that they did not advertise. Thirty-seven companies did not reply to the question. Of the companies resorting to advertising as a means of promoting the growth of the company, 112 reported the use of newspapers for this purpose. Forty-nine reported using special circulars only; and 42 reported using both newspapers and special circulars. Twenty-nine companies merely replied that they did some advertising without specifying the method employed.

Seven hundred twenty-two companies reported compensating their representatives for the solicitation of business by means of a fixed fee per application taken. The maximum of such fee reported by any company was $4 and the minimum was 25 cents. The average fixed fee allowed was $1.28. Only 32 companies reported such fee in excess of $2, while 78 companies reported a fee of less than $1. Fifty-six companies paid both a fixed fee and a small commission based on the amount of insurance written, while 82 companies reported paying for services in soliciting business on a per diem basis. No information concerning the cost of getting business or the method used in compensating for this service was given by 170 companies.

One hundred thirty-one companies reported compensating their officials or agents for the solicitation of business strictly on a commission basis. The average commission allowed by these companies amounted to $0.027 per hundred per year of the insurance written. Only 18 companies allowed a commission equivalent to more than 5 cents per hundred per year, and 62 companies paid such commission equal to less than 2 cents per hundred per year.

The fixed fee plan of compensating solicitors of business in these companies may thus be said to be the current practice, being followed by more than three-fourths of the companies. This plan eliminates all temptation on the part of agents either to encourage or to permit overinsurance.

SALARIES OF DIRECTORS AND OFFICERS.

More or less complete information concerning the compensation of directors and officers was given by 842 companies. In the case of directors each of these companies reported the actual per diem allowed. The largest such per diem was $10 and the smallest was 50 cents. Only 24 companies paid a per diem of more than $3, while 104 companies paid a per diem of less than $1.50. The average per diem paid by the 842 companies was $2.05. The most common amount paid was $2, nearly one-half of the companies reporting this figure.

The question referring to compensation of officers was less generally filled out than were the other parts of the questionnaire, and in view of the variation in the size of the companies, as well as of the different plans in vogue with regard to the distribution of duties among the officers, any figures in the way of averages would have but little significance. A few data bearing on the plans of compensation may, however, be submitted. The president was paid a fixed annual salary by 410 companies, while 85 reported paying a fixed allowance per policy in force during the year, and 56 others reported a combination of these two methods in the compensation of this officer. In the case of the secretary, 423 companies reported paying a fixed annual salary; 98 reported compensating this official on a per diem basis, and 139 reported paying a fixed allowance per policy in force during the year. In the case of the treasurer, 315 companies paid a fixed annual salary; 118 reported compensating this official on a per diem basis; and 166 reported paying him on the basis of percentage of money handled. Forty-one companies used a mixture of two or more of these methods as a basis for the compensation of the treasurer. Out of 188 companies which reported the compensation of a secretary-treasurer, 122 paid an annual salary; 13 companies paid a per diem; and 13 paid a fixed allowance per policy in force, while 40 companies used a combination of two or more of these methods. The prevailing plan of compensation for directors and officers of these organizations is therefore that of a per diem for the directors and an annual salary for the officers charged with the routine work of the company.

ADJUSTMENT OF LOSSES.

Information concerning the agency used in the adjustment of losses was furnished by 1,143 companies. Of these, 178 reported having a committee charged with this duty, while 119 reported employing special adjusters. In the case of 404 companies the adjustment of losses was left entirely to the directors while in the case of 97 com-

panies one or more of the officers were charged with this duty. The 345 other companies giving information on this point reported various combinations of the plans already given. So far as any plan can be spoken of as most common it is that of leaving the adjustment of losses to the directors, each acting for the company as a rule in his own neighborhood. While this plan may be the cheapest, a greater uniformity in adjustments is doubtless secured by employing in so far as possible the same official or employee of the company for all adjustments.

Seven hundred sixty-one companies reported providing in their by-laws for appeal to a special arbitration committee in the case of disagreement with the insured as to the indemnity due him. Sixty-eight companies reported that the insured had the privilege of an appeal to the board of directors in the case of such disagreement, and 76 other companies had various arrangements to cover cases of disputes with the insured in connection with the adjustment of losses. Twelve companies stated that no provision was made in their by-laws covering cases of disagreement, while 244 companies did not answer the question relating to this matter.

SURPLUS AND REFUNDS.

The replies of 764 of the 1,091 companies which gave information concerning the policy of the company with regard to a reserve or surplus stated that the company did not make any effort to keep on hand any surplus fund, and 57 companies simply reported a specific amount now on hand. Seventy-five companies made an effort to have on hand a surplus equal to a fixed percentage of the insurance in force, while 19 companies aimed to keep on hand a surplus based on the premium collected on policies then in force. The reports received from 176 companies indicated that they had "some" surplus on hand without either giving the amount of such surplus or stating the plan followed by the company with regard to the amount of such fund. The large majority of these companies, therefore, have no fixed plan with regard to reserve or surplus. The maintenance of a reasonable surplus appears to be favored to an increasing extent, however, by the leading representatives of farmers' mutual insurance. A surplus amounting to $2,000 or $3,000 per million of insurance in force is generally considered to be sufficient for companies whose risks involve no conflagration hazard.

Only 648 companies gave replies to the question covering the policy of the company in respect to the return of excess premium deposits and only 37 of this number reported actually making any such refund to the policyholder, thus again indicating that the majority

of these companies operate strictly on the assessment plan and collect from time to time from their members only such amounts as will suffice to pay losses and expenses.

REINSURANCE.

Eight hundred ninety-one of the 1,161 companies returning questionnaires gave replies to the question covering reinsurance. Of these only 67 reported having a part of their risks reinsured, while 824 companies stated specifically that none of their risks were reinsured. Suitable reinsurance facilities are among the great needs of many of these companies, a need that only recently has begun to be more generally recognized by them. In one State, namely, Iowa, a special reinsurance company has been organized by the farmers' mutuals, and in Illinois the law was recently amended so as to permit these companies to place reinsurance with one another. Such privilege has for some time been granted by the laws of Wisconsin, Iowa, Missouri, Nebraska, Kansas, Kentucky, and Colorado. The Minnesota law permits the companies to write joint or concurrent insurance in conjunction with other farmers' mutuals, on property located outside of the prescribed business territory. All State laws on this subject should permit the farmers' mutuals to reinsure a part of their larger risks with one another, and should also permit these companies to write policies of joint or concurrent insurance outside of their special territory in order that they may be encouraged by one plan or another to avoid exposing themselves to excessive losses.

CONCLUSION.

The preceding summary, while pointing out the prevailing plans and practices among farmers' mutuals, also brings out clearly the variety in such plans and practices. In 16 of the States, associations of mutuals have been organized. These associations hold either annual or biennial conventions at which the officers of the member companies have an opportunity to compare methods and discuss plans for the improvement of their organizations. Such associations should be formed in all States where farmers' mutuals exist. The National Association of Mutual Insurance Companies, which holds annual conventions, is in large measure composed of farmers' companies. These intercompany associations are a powerful influence tending toward the improvement and standardization of the plans and practices of farmers' mutuals as well as of other mutuals that avail themselves of membership in them. While rigid uniformity may not be desirable, a reasonable approach to uniformity in the plans and practices of the farmers' mutual fire insurance companies, at least within a given

State, would be a material advantage. The general public would be more easily convinced of the soundness and real value of these companies as a class. The approval and support of the insurance department of the State would be more easily secured than is sometimes the case under present conditions. Financial institutions which lend money to farmers would more readily accept the policies of these companies as collateral, and lastly the companies themselves would find it easier to cooperate with one another in matters of reinsurance or joint insurance, as well as in meeting other problems that arise.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE OF SPECIAL INTEREST TO THOSE CONNECTED WITH FARMERS' MUTUAL FIRE INSURANCE COMPANIES.

PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

Cotton Warehouse Construction. (Department Bulletin 277.)

Dust Explosions and Fires in Grain Separators in the Pacific Northwest. (Department Bulletin 379.)

The Organization and Management of a Farmers' Mutual Fire Insurance Company. (Department Bulletin 530.)

Grain-Dust Explosions, Investigation in the Experimental Attrition Mill at the Pennsylvania State College. (Department Bulletin 681.)

Prevailing Plans and Practices Among Farmers' Mutual Fire Insurance Companies. (Department Bulletin 786.)

Modern Methods of Protection Against Lightning. (Farmers' Bulletin 842.)

Fire Prevention and Fire Fighting on the Farm. (Farmers' Bulletin 904.)

Farmers' Mutual Fire Insurance. (Separate 697, from Yearbook 1916.)

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BULLETIN No. 787

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

Washington, D. C. June 9, 1919

PROTECTION FROM THE LOCUST BORER.

By F. C. Craighead,
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CONTENTS.

INTRODUCTION.

The increasing value of black or yellow locust[1] for many purposes, and especially the recent demand for sound locust pins or tree-nails in the construction of wooden ships, render its protection from insect damage important.

In addition to the natural growth of locust in forests, farmers' woodlots, and abandoned fields, many attempts have been made to grow it on a commercial scale in plantations. These attempts in most cases have resulted in failure, owing to the serious damage to the wood and frequently the destruction of the trees caused by the locust borer.[2] The fact, however, that in natural growth and occasional plantations practically no injuries from the borer are found, while in other cases the trees are ruined for commercial purposes or killed outright, has led the writer to make a thorough investigation of the problem to ascertain the cause of the occasional immunity from borer injury.

As a result of these investigations, it appears practically certain that *plantations of this tree can be protected successfully from*

[1] *Robinia pseudacacia* L.

[2] *Cyllene robiniae* Forst.

the borer and grown profitably on a commercial scale if the locusts are planted in thick stands or mixed with other trees so as to produce a densely shaded condition and natural pruning during the first 10 to 15 years of growth.

HISTORICAL.

The great variation in the extent of injury by borers to both planted and natural stands of black locust has been noted by many writers. In fact, as early as 1821, Pickering (2)[1] stated that trees of natural growth in groves were much less liable to injury than were transplanted trees. Schwarz (3) in 1890 observed that the insect lives in large colonies affecting all trees of small groves, while long hillsides full of locust are not infested. Cotton (5) observed that in Ohio injury was greater in single trees and plantations of considerable size than in natural forests. Hopkins (6) remarked that "Favorable conditions for the destructive work of the borer appear to be found in the presence of isolated trees and groves in the open. . . . Unfavorable conditions are found in forest growth or large areas of pure stands, or mixed stands where the locust predominates; also, in plantations and groves where resistant varieties prevail, and where there is no goldenrod or other favorite food for the beetles." Dearborn (1), Kellogg (4), and Garman (7) also call attention to this fact.

OBSERVATIONS BY THE WRITER.

In examining locust plantations during the last few years, the writer was greatly impressed with the absolute destruction of some tracts, while others, or parts of the same tracts, were thrifty and unmarred by borers. This was convincing evidence that the trees could be grown so as not to be injured by the locust borer. Many tracts, therefore, both planted and natural, were studied with the idea of securing evidence that might be applicable in a practical way. As far as possible the accurate history of many locust stands, both pure and mixed, was obtained and factors that might be responsible for the presence or absence of injury were weighed. As a result of such study, it was found that the amount of destruction was unquestionably greater in those tracts which had been pruned occasionally, closely grazed, or in which fire had gone through from time to time, killing out the underbrush and destroying the natural shade produced by weeds or shrubbery. The denser the growth, particularly weeds and undergrowth about the stem of the tree, the less was the amount of borer work and vice versa. Pure stands in open fields, where the trees were growing from 2 to 3 feet apart, were seldom injured, while near-by isolated trees were riddled by the borer.

[1] Reference is made by number in parenthesis to "Literature cited," p. 12.

Possible reasons for such immunity in dense stands were discussed with Dr. A. D. Hopkins in several letters during May, 1910. In a letter of May 11 Dr. Hopkins wrote:

> Perhaps with the unpruned trees there is more shade and, since the beetles are sun-loving and active during the day, the more open and light conditions found in the pruned groves may serve as the attractive influence. This is the only thing I can think of that would make the difference. Observations should be made during the period of flight to determine the relative number of beetles found on trees under shaded and sunny exposures.
>
> If this should lead to a solution of the problem and shaded conditions are favorable, then mixed planting with some quick growing tree like catalpa might be advisable.

This seems a very plausible theory to account for the immunity of unpruned and natural growths, and it is substantiated in the experiments conducted. No other factors considered seem to cover the conditions in the many localities where trees were examined.

INVESTIGATIONS AND EXPERIMENTS.

Natural growths of locust in the vicinity of Falls Church, Va., and plantations along the Pennsylvania Railroad right of ways were selected and used as experimental plats. Some of these near Falls Church were pruned while others were left as they were found. The history of plantations along the Pennsylvania Railroad as to planting and subsequent management has been furnished by the office of the forester of the railroad, which also provided facilities for the study of these plantations.

NATURAL GROWTH IN THE VICINITY OF FALLS CHURCH, VA.

1. On Miners Hill there is a stand of mixed growth of reproduction averaging 3 to 5 inches in diameter. The aspect is a westerly slope, the trees extending from the crest more than half way down the hill. It contains about an acre and is composed chiefly of oak, chestnut, tulip, persimmon, hickory, sassafras, maple, and locust. It is thickly undergrown with weeds and briers which now are dying out. The locust composed about 5 per cent of the stand. In the fall of 1915 these locusts were from 2 to 3 inches in diameter and contained no borers. In January, 1916, one end of this plot, constituting about one-tenth of the area, was pruned; all trees, except the locust, were cut out. The following fall adult beetles were observed ovipositing on the trees thus isolated, and examination in the spring of 1917 showed from 3 to 10 borers in each tree. Again in 1918 these trees were found to be heavily infested. In the remainder of the stand (that which is still growing naturally) about 1 tree in 10 can be found containing one or rarely two defects made by the borer.

2. Just across a road from the tract described above is an old orchard which is used as a pasture. About two dozen locusts of the

same age are growing here. These trees are gnarly, some broken off, and all heavily infested. In the spring of 1918, 10 to 35 larvæ were found in each of these trees. The cattle have kept down the weeds and underbrush which would otherwise protect the trunks.

3. In the same general locality, about one-half mile north of these tracts, lies an abandoned field covered with an almost pure stand of virgin scrub pine 12 to 14 years old. Mixed in this pine are quite a few locusts. During the winter of 1915–16 about an acre of this pine was cleared. The locusts, then averaging 4 inches in diameter, were left standing. None of the trees were infested, as were none of those in the midst of the remaining pine. All were straight, naturally well-pruned, thrifty trees. In the fall of 1916 these trees were attacked by the beetles, and many larvæ were found in them in the spring of 1917. The land has not been cultivated, so that a dense growth of weeds conceals the trunks for 6 to 8 feet above the ground. Scarcely any adults were found on these trees in the fall of 1918, and very few larvæ are expected in the spring of 1919.

In January, 1918, another part of this pine wood was cleared, leaving 15 trees exposed. In July the trees were examined and no borers found nor any evidence of injury in the past. During August and September, 1918, adults were observed ovipositing on these trees.

4. Another abandoned field on an easterly slope contains a clump of about a hundred small locusts, 2 to 6 inches in diameter, grouped about several large trees. These are closely spaced, averaging 2 feet apart. They are well mixed with sumac, tulip, and sassafras. In the surrounding field are many isolated trees. All these isolated trees are scrubby and badly infested by repeated borer attack, while those in the dense clump are tall, thrifty, and contain no borers or defects from past injury.

5. Another abandoned field one-half mile north of Green Gables station on the Washington and Virginia electric line contains several groups of locust from 6 to 18 years of age and many isolated trees. This field contains about 100 acres. Clumps of sassafras and pine mixed with locust and persimmon occupy much of the remaining area. Broom sedge and goldenrod cover the ground on all open spots. All isolated locusts are heavily infested and have been damaged severely by the borers. Many of these trees have fallen over (Pl. I, fig. 1).[1] Three excellent stands of locust occur here; one group of an almost pure stand is composed of trees 25 to 30 feet high and 6 to 8 inches in diameter. They grew very close together and have now thinned out to an average of 10 feet apart. There are more than 500 trees in this plot; all are thrifty and no evidence of borers can be found. They represent what can be grown in 18 years' time on

[1] The photographs were taken by Mr. R. A. St. George, scientific assistant, Forest Insect Investigations, Bureau of Entomology.

FIG. 1.—NATURAL GROWTH OF LOCUST IN AN OLD ABANDONED FIELD OF SOME 60 ACRES IN EXTENT AT FALLS CHURCH, VA.

Trees badly infested by the locust borer. Several killed and others blown over. Note scattered position. Diameter near base, 2 to 6 inches.

FIG. 2.—NATURAL GROWTH OF LOCUST IN AN OLD ABANDONED FIELD OF SOME 60 ACRES IN EXTENT AT FALLS CHURCH, VA.

Several old seed trees and surrounding root sprouts and seedlings. Note thick growth. None of these trees are infested. Diameter near base, 1 to 8 inches.

PROTECTION FROM THE LOCUST BORER.

FIG. 1.—NATURAL GROWTH OF LOCUST IN AN OLD ABANDONED FIELD OF SOME 60 ACRES IN EXTENT AT FALLS CHURCH, VA.

An isolated clump of some 30 trees, 2 to 4 inches in diameter. These were growing close together and mixed with tall weeds and sassafras bushes. Illustration after clearing the trunks in July when not a single borer was present. In September these were heavily infested.

FIG. 2.—ILLUSTRATION OF A FENCE ROW AT FALLS CHURCH, VA., SHOWING THICK LOCUST GROWTH OF 2 TO 5 INCHES IN DIAMETER NEAR BASE.

None of these trees contained borers in July, 1918, when the underbrush and small branches were cleared from the trees in the foreground. These trees were infested in September.

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FIG. 1.—A DENSE GROWTH OF ROOT SUCKERS FROM A FEW OLD TREES THAT WERE REMOVED, ON MINERS HILL NEAR FALLS CHURCH, VA.

This illustrates the type of growth that will not be attacked. In the background to the right of the road are many trees containing 5 to 20 borers each. It illustrates the pruned portion of example 1 (see p. 3).

FIG. 2.—LARGE MATURED LOCUSTS AT VIENNA, VA., SHOWING WHAT CAN BE GROWN IN A LOCALITY WHERE THE BORERS ARE VERY ABUNDANT.

These trees show no evidence of borer injury.

PROTECTION FROM THE LOCUST BORER.

old waste land, the soil of which has been enriched by a thick bed of humus beneath the trees.

Another group (Pl. I, fig. 2) near by contains about 30 trees similar in respect to size and conditions. These have seeded the surrounding soil so that a large clump is formed of dense growth, the outermost being some 6 to 8 feet high. None of these trees have been injured by the borer. A third group (Pl. II, fig. 1), forming a small oval clump, contains 38 trees from 2 to 4 inches in diameter and 15 feet high. They were closely set, averaging 4 feet apart. A few sassafras were intermixed. In July, 1918, not one of these trees contained a borer. August 20, 1918, the plot was thinned, all branches trimmed to 8 or 10 feet, and all weeds and briers removed. The trees were closely watched and many adults were observed ovipositing on them during September.[1] Adults were likewise observed on the isolated trees near by, but none in the dense plats described above.

6. A fence row opposite the eastern field station at Falls Church, Va., is densely matted with wild cherry, honeysuckle, and goldenrod along the sides. Through this grow a dozen locusts (Pl. II, fig. 2) 2 to 4 inches in diameter. None of these trees were infested on or previous to August 15, 1918, on which date all the surrounding growth was cleared from four trees. During September adults were observed ovipositing on these four. Many such fence rows exist wherever locust is grown and explain why so little trouble is experienced on the average farm.

7. Along the south bank of the Potomac River between Difficult Run and Scotts Run many locusts are growing on the wooded slope. This stand is a hardwood mixture composed chiefly of oak, chestnut, hickory, tulip tree, basswood, and butternut. All the locusts are tall, straight poles, reaching to the top of the stand, the trees averaging from 6 to 18 inches in diameter. All show a thrifty condition of growth and no borer defects. A low meadow, sometimes cultivated but now pastured, lies between this river terrace and the water. A few occasional locusts grow here, nearly all of which are infested and badly deformed. No goldenrod occurs in the meadow, and the adult beetles were observed to feed on several species of Eupatorium.

PLANTATIONS ALONG THE PENNSYLVANIA RAILROAD.

From the office of the forester of the Pennsylvania Railroad records have been secured of 42 plantations, comprising nearly 2,000 acres, on which over 1,000,000 trees were planted. These trees were about 2 years old when set out and usually were spaced 8 by 8 or 8 by 10 feet. Many of these tracts were personally examined by the writer, accompanied by Mr. I. T. Worthley, assistant forester. The history of each plantation was ascertained as accurately as possible.

[1] Examination of this plot on Apr. 8, 1919, showed an average of 15 borers per tree.

Some of these tracts are in excellent condition, others almost totally destroyed. It is necessary to describe only a sufficient number of these to give all conditions of culture and past history.

8. Along the line of the railroad, between Philadelphia and Harrisburg, Pa., near Kinzers, are two locust plantations, one on the south side planted in 1904, one on the north planted in 1905. Together they comprise about 25 acres, containing 44,000 trees. As far as can be ascertained, nothing was done in these plots until 1909 and 1910, when thorough prunings took place. The entire tracts were gone over and all the trees trimmed to a single straight stem. All natural growth of other trees or shrubs was thinned out. The writer personally assisted in one of these thinnings in 1910 and at that time noted a few borers in the larger trees. Nothing more was done, but an examination in 1912 showed the borer very abundant and many trees breaking off. At present it is difficult to find a good tree. A few have not been injured sufficiently to cause them to break, but the great majority form a broken tangle. Many root sprouts and suckers are present. These are now meeting the same fate.

9. Near New Brunswick, at Stelton, N. J., are several more plantations in a long strip on the old roadbed comprising some 8 or 10 acres of 13,000 trees. One of these lies along the present roadbed near the station. These trees have been pruned from time to time by the section crews. At present they are badly infested (in the spring of 1918 averaging 10 living borers to a tree) but few broke off until the summer of 1918, when a severe wind destroyed about 5 per cent. These trees average 2 to 5 inches in diameter.

Farther west, some distance from the present roadbed, is a similar stand planted at the same time. No care was taken of it and the trees grew up in thick weeds and other natural, shrubby growth. They are scarcely close enough to produce much natural pruning and all have several large branches. An examination in 1917 and 1918 showed that only a very few trees were infested or ever had been infested. The average diameter is larger than that of those nearer the station.

10. One mile east of Metuchen, N. J., are 10,000 trees planted in 1909, divided into about equal stands, one on the south and one on the north side of the roadbed. The north plot was pruned at two different times, but the years could not be determined. In the spring of 1918 all these trees were badly infested and many were broken off. Many root sprouts and suckers have grown out. The trees on the south side never were pruned or thinned. In the spring of 1918 it was almost impossible to find a borer in the tract; however, a certain amount of old work was present, though not sufficient to mar the trees greatly. These trees were not planted close enough to cause natural pruning and consequently are considerably branched. Very

few root sprouts occur in this tract. They are now producing a more dense shade and natural pruning is taking place. At an earlier date, when the trees were less dense, borers attacked, but as the density increased they probably were repelled before the trees were seriously injured.

The diameter of the stand on the south side averages several inches more than that of the standing trees on the north side. If these trees on the south side had been planted several feet closer, say 6 by 6 instead of 8 by 10 feet, it is the writer's opinion that they would now have unbranched stems with practically no borer defects.

11. On the low-grade freight line between Martic Forge and Columbia, Pa., are five plantations set out in 1906 containing about 150,000 trees. None of these have ever received any attention in the way of pruning. They present conditions varying from such as described at Kinzers (example 8) to almost perfect stands free from borer injury. In no single plantation are the trees all destroyed or all in good condition, but the extremes are found in different parts of each tract. Another factor has been responsible here. A definite correlation exists between those parts of the plantation that have been run over by fire and those parts which were by nature of their position less subject to fire. Where fire has burned over repeatedly, killing the undergrowth, the worst destruction by borers is found. In many places the locusts themselves have been killed. One tract near Shenks Ferry attracted particular attention. It extends from the roadbed across a bottom and up over a hillside. Fire no doubt has gone through the part near the tracks repeatedly, as evidenced by the different ages of scars on the standing trees. Here there is little undergrowth; the locusts are scattered (many have been fire-killed), and all are severely infested. On the hillside and over the crest, fires, for some reason, have not gone through. The locusts have grown up in a dense stand mixed with much underbrush, and oak and chestnut sprouts from the original stumpage. These trees are now in excellent condition; they are tall, straight, thrifty, not branched, and free from borer defects. In some parts the shade of the mixed stand has become so dense that all weeds, briers, and underbrush have been shaded out.

12. Along the railroad between Harrisburg and Huntingdon, Pa., much locust has been planted, and many natural stands occur. The condition of the locust in this region is generally so much better and so much more thrifty that the first examination gave the impression that it is an exceptionally favorable situation for the growth of the tree. It is no doubt true that certain localities are better adapted to the growth of black locust, but the essential factor in this location is considered to be more than purely a favorable situation. The locusts are growing in a narrow belt of river terrace from a few

yards to a mile wide between the foot of the mountain and the Susquehanna and Juniata Rivers. There is much humidity, and all vegetation is vigorous.

It is believed that the good condition of these locusts and the decided absence of injury by borers are due to the fact that the situation is conducive to a rapid growth of underbrush and plants characteristic of river shores which have afforded protection to the locusts. This is further emphasized by the fact that in other localities are found trees of equal size and good appearance, as described at Shenks Ferry (example 11), of the same age. Also in the same locality we find trees deformed and aborted by borer injury, as described in the following paragraph.

13. Along the Juniata River between Newport and Old Ferry, Pa., a continuous plantation of locust set out in 1904 extends for a distance of 2 miles. These trees, especially that part near Newport, show the best stand of all the plantations. After planting no attention was given them until 1914, when they were thinned to afford a view of the river from the trains. At this time most of the stems had reached a sufficient size to be immune from borer attack. The trees nearest Newport now average 5 to 8 inches in diameter. They are straight, free from branches, and about as tall as the telegraph poles near by. The bark is ridged naturally, showing absence of borer injury in the past. Nothing definite as to how these trees grew in the period intervening between planting and first pruning could be ascertained, but from a study of many plots of all ages along the river it is certain that they were intermixed with a dense growth of other shrubs and weeds. Natural pruning and thinning have taken place to such an extent that few living branches are found below the crown, and many trees have been suppressed and killed. Farther back from the railroad, where no pruning at all was done, the dead, suppressed trees and shaded-out branches give a good idea as to how rapidly this process takes place in the tree.

In this 2-mile strip of locusts the borers are serious in two places and have caused many trees to break off or have stunted the growth badly. In one of these places fire has gone through: the other was evidently pruned (as shown by scars) to afford a view of a pond just behind. These last trees were also isolated in the sense that the rows were only two trees deep. These trees average scarcely half the diameter of those in the better parts of the grove.

CONDITION OF TREE NECESSARY FOR BORER ATTACK.

All trees and all parts of the tree are not subject to attack by the borer to the same degree.

Moderately rough bark seems to be an essential condition, since it provides the necessary crevices in which the adults deposit their eggs.

Likewise, until they become 1½ to 2 inches in diameter at the base, trees are not subject to attack unless the bark is rough. On younger trees the borers are found concentrated at the base and near crotches.

For some unknown reason trunks of trees reaching 5 to 6 inches in diameter and over (excepting old brood trees) rarely are found to contain borers. On such trees the larger branches frequently are infested, but such injury is seldom common enough to do much harm or even attract attention. It can be said, therefore, that protection from borer injury is necessary for only a comparatively short period during the tree's growth. Under good growing conditions this time should not exceed 10 years.

In every locust grove that has borers present, certain trees will be found on which they have concentrated. These are called brood trees. The thick, irregularly barked, gnarled appearance and stunted growth will distinguish such individuals. They are often continuously infested until they reach an old age, or 12 to 18 inches in diameter.

HOW TO RECOGNIZE TREES CONTAINING NO BORER DEFECTS.

The larval mine made by the locust borer destroys a certain amount of the growing tissue or cambium and makes a serious defect in the wood. This injury to the cambium accelerates growth to heal it over and produces a swollen or gnarly appearance. Many such defects give the entire stem a roughened, distorted shape. The bark is irregular and scaly. On the other hand, trees that have not been injured by the borer are characterized by very regular bark, which is grooved longitudinally between thick, dark ridges. With a little experience these features can be quickly recognized and until the tree reaches 10 to 12 inches in diameter it is possible to determine accurately whether the borer defect will be found in the wood.

CHARACTER OF GROWTH OF UNINFESTED STANDS.

Not only is the appearance of uninjured individual trees characteristic but pure stands of such trees have a different appearance from those that are damaged. The tops of isolated natural stands have a domelike outline, the innermost trees growing taller and straighter, while root sprouts continuously coming up around the borders form smaller and younger trees which give additional protection to those within. These younger trees are at first too small for infestation, and when they have reached a susceptible size are protected in their turn. The crowns are uniformly shaped and no branches project to break the contours. Planted stands, where the trees are of the same age, are uniform in height, the tops forming a flat outline. No large branches are found on the trunks, but many

small, naturally pruned dead branches are seen and many trees are thinned out naturally as the others increase in size. Few root sprouts appear. Infested plantations are very irregular in outline; broken tops, trees of irregular size, and many root sprouts and suckers are characteristic indications of borer damage.

CONDITIONS UNDER WHICH LOCUST CAN BE GROWN.

From the history of the foregoing tracts it is evident that black locust can be grown profitably under circumstances that require little care, or, in fact, better results are obtained without too much attention. After comparing all the data available it seems that *provision for sufficient shade during the period of growth subject to borer attack* is all that is necessary in order that this tree may be grown successfully.

This can be achieved by some system of close and mixed planting. Experiments of such a character should be tried. In nature it is accomplished by close reproduction coming up around the seed tree, by root sprouts from older trees, or often by the mixture of other plants growing with the locusts. Weeds and vines often form the needed shade, as illustrated by trees in old fence rows. It is very essential that this shade be present after the trees reach 1½ to 2 inches in diameter, and that it be continued until they attain 5 or 6 inches. After this time thinning and pruning can be done with little or no subsequent injury by the borers.

Close planting or thick growth of these trees also is necessary to produce straight, unbranched boles. Trees in the open are always much branched and rather crooked, but those grown in forests are tall, straight, and naturally pruned while the branches are quite small.

That difference in site or locality is not the influencing factor in the growing of uninjured trees is evident from the fact that in every locality examined it was possible to find examples of borer-free and destroyed trees growing 100 yards apart. It is also evident that goldenrod is not necessarily associated with greater damage by the borer, for in the same abandoned field, massed with this plant, were found plots of trees absolutely free from injury and near-by isolated trees badly infested. Again, localities where no goldenrod is growing may have borer-infested trees, the adults feeding on other composites, as illustrated by example 7.

The idea has been advanced that the borers are more abundant in some localities than in others and that this will account for the difference in infestation. This difference can not be sustained, as the beetles are present everywhere within the natural range of this tree. Side by side we find stands of badly infested trees and trees containing no borers. It is rather to be believed that in localities where locust

was planted the beetles present either remained in about the same numbers or increased enormously, according as the condition of the trees retarded or favored their increase. In no new locality where plantations were put out would there be enough beetles present to infest all the trees. They only attack all the trees as they become sufficiently numerous.

CONTROL.

A METHOD OF HANDLING SEVERELY DAMAGED PLANTATIONS.

Many locust plantations have been abandoned and all hope of ever realizing any commercial product given up because of the severe devastation produced by the borers. Such tracts look hopeless with the greater percentage of the trees broken off or killed, but it is believed that they can be reclaimed after several seasons' care by virtue of the sprouting ability of this tree.

It is recommended that all such plantations be gone over and the broken-down and infested trees removed and burned during the winter. Unless otherwise desired it would be necessary to cut out only the living infested trees, because no beetles will breed in the dead ones. Especial attention should be given to the seriously damaged or so-called brood trees. If the cutting out of the infested trees can be done early in November it is not necessary to destroy or burn the wood. The larvæ require living wood for their early development and will not mature in dead material. This not only will reduce the numbers of the insects, but before the sprouts become large enough to be attacked a sufficiently dense stand will have been developed to provide natural protection, as illustrated in Plate III, figure 1.

TREATMENT OF SHADE TREES.

The locust is widely planted for ornamental and shade purposes. It is very desirable for such planting, because of its ability to succeed well in a variety of soils and situations and its rapid growth and good form of crown in the open. We often hear complaints of serious injury by the borer to locust shade trees; this is because such trees are usually grown in isolated situations most favorable for attack.

It has been found that the young borers can be killed readily by the use of an arsenical spray, applied to the bark when the new growth begins to open at the tips of the twigs in the spring. It is necessary to apply this mixture so thoroughly as to cover all parts of the trunk and reach every spot where a larva is working.[1]

A thorough application will probably be necessary only every two years unless there are badly infested trees near by which are not treated and form centers of reinfestation. As a rule, spraying will

[1] The presence of a young borer can be determined by the oozing of sap and boring dust from a small hole through the bark. This hole is enlarged as the larva grows.

not be necessary after the trees reach 6 inches in diameter or such a size that they are immune from attack. Isolated trees, however, are sometimes exceptions to this and should be watched.

Many spray solutions have been tried by the writer, but by far the most successful has been the combination of a soluble arsenate with an oil emulsion. This provides a penetrative poison which enters the exudation pores made by the larvæ through the bark and poisons the inner bark on which the young larvæ feed. Insoluble arsenates are not so effective, as the exudation pore is usually plugged with a wad of fine granular frass from which the arsenate in suspension filters out. Kerosene emulsion can be used to carry the arsenical, but it has been found that the miscible oils are just as satisfactory and require much less time in preparation.

The formula and preparation are as follows:

Dissolve ¼ pound of sodium arsenite or arsenate in 5 gallons of water. Add 1 quart of miscible oil and agitate thoroughly.

With kerosene emulsion, dissolve ¼ pound of the arsenical in 4 gallons of water and add 1 gallon of stock solution of kerosene emulsion, agitating thoroughly.

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MOISTURE IN WHEAT AND MILL PRODUCTS.

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CONTENTS.

INTRODUCTION.

In November, 1914, investigations were begun by the Department of Agriculture at Kansas City, Mo., in cooperation with several flour mills for the purpose of obtaining further information concerning the relative importance of moisture in the wheat kernel from the standpoint of milling. The flour-producing capacity of the mills cooperating in this work ranged from 500 to 3,000 barrels per 24 hours. The investigations, while not of sufficient scope to establish any definite conclusions, are of interest in so far as the results obtained disclose conditions present in the particular cases examined.

In obtaining the samples used in connection with these investigations, great care was exercised that each would be as nearly as possible representative of the particular lot or stream of stock sampled. Upon obtaining the samples they were immediately placed in airtight containers and sealed up until the time of determining the moisture content, which determinations were made in every instance within a week after the samples were drawn. In the case of the wheat samples, their moisture content was determined by use of the Brown-Duvel moisture tester, and in the case of the other samples

(flour, feed, and other mill products), the method used was that of drying to constant weight a small portion of the sample in a water-bath oven, at the temperature of boiling water.

MOISTURE REQUIREMENTS OF WHEAT FOR MILLING PURPOSES.

At the beginning of the process of milling, the miller gives much consideration to the question of the moisture content of his raw material. He knows that in order to secure the highest yields of flour and to insure its greatest purity, the pericarp or outer coatings of the wheat kernel at the time of grinding must be of a certain toughness, and the endosperm, or inner part, of a certain mellowness. The degree to which these properties are possessed by the different parts of the kernel is influenced largely by the amount of moisture present.

Wheat when received at the mill is seldom, if ever, in the best condition for milling, its moisture content being too high, too low, or not properly distributed throughout the kernel. To acquire the right moisture content for the outer and inner parts of the kernel, thereby insuring the best possible milling condition for different wheats, requires the application of various methods of tempering. These methods may consist of a single, or successive, or of combined applications of water, heat, or steam, working through a period of time, ranging from a few minutes to as much as 36 hours, in order that the moisture may be properly distributed within the kernel.

Dry climates and dry seasons naturally produce wheat of low moisture content, and damp climates and wet seasons produce wheat of high moisture content. There is, moreover, often considerable range in the moisture content of wheat during any given season and in any one locality. Moisture determinations of samples obtained from more than 5,000 cars of wheat, which were made by this department at Kansas City, Mo., during the years 1910 to 1914, inclusive, showed a range in the content of that factor from 7.4 per cent to 22 per cent. The fact that the moisture content of wheat may vary so greatly is evidence that the problem of properly tempering wheat is a complicated one.

AMOUNT OF MOISTURE ADDED TO WHEAT DURING TEMPERING.

In Table I is shown the percentage of moisture contained in wheat before and after cleaning and tempering as found from moisture determinations made on a series of samples secured from five different mills. The wheat of each mill was of similar class (hard red winter) and grade, and contained, at the beginning of the tempering process, approximately the same percentage of moisture. Different amounts of water, however, were added by each mill. The difference in moisture content of tempered and untempered wheat as shown in this table indicates the change in that factor which resulted from

cleaning and tempering, but does not represent the entire amount of moisture added.

TABLE I.—*Moisture content of hard red winter wheat before and after cleaning and tempering, as found at five mills.*

Date sampled.	Mill No. 1.		Mill No. 2.		Mill No. 3.		Mill No. 4.		Mill No. 5.[1]	
	Before.	After.	Before.	After.	Before.	After.	Before.	After.	Before.	After.
1915.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Nov. 30	14.00	16.15	13.95	15.50	14.00	15.10	13.40	14.35	13.20	14.15
Dec. 1	14.20	16.70	13.60	15.60	(2)	(2)	12.70	13.85	12.75	14.40
Dec. 2	13.20	16.40	13.65	15.30	14.15	14.50	14.35	15.50	13.05	14.65
Dec. 3	13.50	16.40	13.95	16.25	13.75	15.00	13.35	14.10	13.20	14.45
Dec. 4	14.15	16.70	13.80	15.80	14.65	15.75	13.10	14.95	12.85	14.10
Dec. 6	(2)	(2)	13.75	15.95	14.50	15.60	13.85	14.20	13.60	14.00
Dec. 7	13.85	16.35	13.40	15.70	14.15	15.20	13.95	(2)	13.00	14.30
Dec. 8	(2)	16.20	13.05	15.20	13.65	15.20	13.50	14.15	13.55	14.15
Dec. 9	13.85	15.50	12.90	15.10	14.00	15.00	13.00	14.30	13.20	13.40
Dec. 10	14.00	16.35	13.85	15.85	13.80	14.55	13.30	14.20	13.15	13.55
Dec. 11	13.65	16.35	13.75	15.05	14.00	14.90	14.55	15.40	13.20	13.65
Dec. 13	13.10	15.70	13.40	15.90	13.60	15.30	12.80	14.00	13.50	14.85
Average	13.75	16.26	13.59	15.60	14.02	15.10	13.49	14.45	13.19	14.14
Average increase	2.51		2.01		1.08		0.96		0.95	

[1] The wheat milled at mill No. 5 contained about 10 per cent of durum wheat.
[2] No sample obtained.

The lowest moisture content for tempered wheat recorded here is shown to be 13.4 per cent and the highest 16.7 per cent. The former appeared in the case of mill No. 5 and the latter in the case of mill No. 1. The average moisture content for the five mills ranged from 14.14 per cent for mill No. 5 to 16.26 for mill No. 1.

The average increase in moisture content resulting from tempering for the period indicated is shown to have been 2.51 per cent for mill No. 1; 2.01 per cent for mill No. 2; 1.08 per cent for mill No. 3; 0.96 per cent for mill No. 4; and 0.95 per cent for mill No. 5. From these results it appears that a diversity of opinion existed among the millers of these mills as to the amount of moisture hard red winter wheat should contain in order to be properly tempered.

MOISTURE CONTENT OF WHEAT AND VARIOUS STREAMS OF MILL STOCK.

Table II shows the moisture content of the different streams of mill stock and the yield of the various commercial products of three large mills. The arranging of the data in this table was difficult because of the dissimilarity of the processes used at the three mills. The system of separating and grading the stock for subsequent reduction at certain steps was not carried out to an equal extent for all the mills; consequently, certain streams of stock found in one mill were not found in the others nor were streams of stock bearing the same name always of similar character.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data.*

PART 1.—*Effect of the process of preparation for milling upon the moisture content of the wheat.*

Wheat.	Mill No. 1, hard red winter.	Mill No. 2, hard red winter.	Mill No. 3, soft red winter.
	Per cent.	*Per cent.*	*Per cent.*
Moisture content before cleaning and tempering	12.40	13.90	14.04
Moisture content after cleaning and tempering	16.00	13.80	14.67
Effect on moisture content of cleaning and tempering	3.60 gain.	.10 loss.	.63 gain.

PART 2.—*Moisture content of the various roll streams before and after grinding, and the loss or gain in that factor resulting therefrom.*

Stream.	Mill No. 1.			Mill No. 2.			Mill No. 3.		
	Moisture content.		Effect of grinding on moisture content.	Moisture content.		Effect of grinding on moisture content.	Moisture content.		Effect of grinding on moisture content.
	Before grinding.	After grinding.		Before grinding.	After grinding.		Before grinding.	After grinding.	
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
First break	16.00	15.27	0.73 loss.	13.80	13.90	0.10 gain.	14.67	14.78	0.11 gain.
Second break	15.46	15.23	.23 loss.	14.19	13.85	.34 loss.	15.15	14.90	.25 loss.
Second break chunk	15.26	14.75	.51 loss.						
Third break	15.73	15.08	.65 loss.	14.02	13.35	.67 loss.	15.06	14.67	.39 loss.
Third break chunk	15.16	14.82	.34 loss.						
Fourth break	15.44	14.82	.62 loss.	14 42	13.83	.59 loss.	14.82	14.72	.10 loss.
Fourth break chunk	14.96	14.53	.43 loss.						
Fifth break	15.33	(1)		13.73	13.88	.15 gain.	14.37	14.26	.11 loss.
Sixth break	14.96	14.61	.35 loss.				14.19	14.12	.07 loss.
First sizings	13.83	13.48	.35 loss.	13.74	13.72	.02 loss.	13.24	12.65	.59 loss.
Second sizings	13.91	13.55	.36 loss.	13.94	13.43	.51 loss.	14.06	13.56	.50 loss.
Third sizings:									
Grade (*a*)	13.55	13.28	.27 loss.	12.73	12.14	.59 loss.			
Grade (*b*)	13.34	13.03	.31 loss.						
Third break sizings				13.00	12.53	.47 loss.			
First middlings:									
Grade (*a*)	14.16	13.48	.68 loss.	14.00	13.64	.36 loss.	13.75	13.48	.27 loss.
Grade (*b*)	13.50	13.14	.36 loss.	13.58	13.40	.18 loss.	13.23	12.93	.30 loss.
Grade (*c*)	13.93	13.53	.40 loss.	13.33	13.27	.06 loss.	13.87	13.64	.23 loss.
Grade (*d*)	13.42	13.28	.14 loss.						
Grade (*e*)	12.81	12.77	.04 loss.						
Grade (*f*)	13.44	13.39	.05 loss.						
Second middlings:									
Grade (*a*)	13.79	13.41	.38 loss.	13.69	13.32	.37 loss.	13.11	12.75	.36 loss.
Grade (*b*)	13.27	12.99	.28 loss.	13.30	12.89	.41 loss.	12.82	12.28	.54 loss.
Grade (*c*)							13.68	13.37	.31 loss.
Second middlings granulator	12.93	12.47	.46 loss.						
Third middlings:									
Grade (*a*)	12.93	11.73	1.20 loss.	13.24	12.90	.34 loss.	13.14	12.80	.34 loss.
Grade (*b*)	12.94	11.75	1.19 loss.						
Third middlings granulator	13.69	13.27	.42 loss.						
Fourth middlings:									
Grade (*a*)	13.20	13.07	.13 loss.	12.67	12.65	.02 loss.	12.45	12.19	.26 loss.
Grade (*b*)	12.67	12.38	.29 loss.						
Fifth middlings:									
Grade (*a*)	12.63	12.04	.59 loss.	12.39	11.78	.61 loss.	12.24	11.38	.86 loss.
Grade (*b*)	13.15	12.70	.45 loss.						
Sixth middlings	11.68	11.15	.53 loss.				11.89	11.08	.81 loss.
Seventh middlings	12.42	12.01	.41 loss.				12.56	11.80	.76 loss.
First tailings:									
Grade (*a*)	13.00	12.70	.30 loss.	12.81	12.51	.30 loss.	12.01	11.59	.42 loss.
Grade (*b*)	13.32	13.17	.15 loss.	13.36	12.83	.53 loss.			
Second tailings:									
Grade (*a*)	12.40	12.23	.17 loss.	12.89	12.18	.71 loss.	12.37	11.73	.64 loss.
Grade (*b*)				12.23	12.04	.19 loss.			
Third tailings	12.97	13.22	.25 gain.	12.55	12.06	.49 loss.	11.82	11.75	.07 loss.
First low grade	11.85	11.18	.67 loss.	12.16	11.83	.33 loss.	11.41	10.98	.43 loss.
Second low grade	11.20	11.05	.15 loss.	12.18	11.86	.32 loss.			
Third low grade	11.17	11.00	.17 loss.						

[1] No sample obtained.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data*—Continued.

PART 2.—Continued.

Average loss in moisture content of stock resulting from grinding

	Mill No. 1.	Mill No. 2.	Mill No. 3.
	Per cent.	*Per cent.*	*Per cent.*
Average for breaks	0.482	0.270	0.135
Average for reductions	.367	.358	.452
Average for all	.392	.340	.370

PART 3.—*Moisture content of the flour resulting from the different grinding operations.*

Flour.	Mill No. 1.	Mill No. 2.	Mill No. 3.
	Per cent.	*Per cent.*	*Per cent.*
First break	13.73	[1] 13.55	14.25
Second break	14.65	[2] 13.50	14.39
Second break chunk	.....	.....	.....
Third break	14.11	.....	14.21
Third break chunk	.....	.....	.....
Fourth break	14.10	.....	14.39
Fourth break chunk	.....	.....	.....
Fifth break	13.68	[3] 12.67	14.16
Sixth break	[4] 12.21	.....	13.92
First sizings	12.95	13.61	12.71
Second sizings	.....	13.21	13.77
Third sizings:			
Grade (a)	.....	12.45	.....
Grade (b)	12.88	.....	.....
Third break sizings	.....	12.12	.....
First middlings:			
Grade (a)	12.80	12.72	13.16
Grade (b)	.....	.....	13.09
Grade (c)	.....	.....	13.54
Grade (d)	.....	.....	.....
Grade (e)	.....	.....	.....
Grade (f)	.....	.....	.....
Second middlings:			
Grade (a)	12.46	12.92	13.46
Grade (b)	.....	.....	.....
Grade (c)	.....	.....	.....
Second middlings, granulator	.....	.....	.....
Third middlings:			
Grade (a)	12.16	12.95	12.59
Grade (b)	.....	.....	.....
Third middlings, granulator	.....	.....	.....
Fourth middlings:			
Grade (a)	12.34	12.24	12.17
Grade (b)	.....	.....	.....
Fifth middlings:			
Grade (a)	12.05	11.96	[5] 11.96
Grade (b)	.....	.....	.....
Sixth middlings	11.31	.....	[6] 12.24
Seventh middlings	11.92	.....	[7] 12.15
First tailings:			
Grade (a)	12.87	12.05	11.25
Grade (b)	.....	12.87	.....
Second tailings:			
Grade (a)	12.08	12.18	12.68
Grade (b)	.....	12.02	.....
Third tailings	[8] 13.02	11.90	.....
First low grade	11.23	11.70	11.11
Second low grade	11.53	11.77	.....
Third low grade	11.05	.....	.....

[1] Includes flour from fourth break.
[2] Includes flour from third break.
[3] Includes flour from shorts duster and tail of rebolter.
[4] Includes flour from bran duster.
[5] Includes flour from third tailings.
[6] Includes flour from bran duster.
[7] Includes flour from shorts duster.
[8] Includes flour from sizings duster.

TABLE II.—*Moisture content of samples of different streams of mill stock secured from three large mills, and other data*—Continued.

PART 4.—*Moisture content and relative milling yields of the different commercial products of each mill.*

Product.	Mill No. 1.		Mill No. 2.		Mill No. 3.	
	Moisture content.	Milling yield.	Moisture content.	Milling yield.	Moisture content.	Milling yield.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Patent flour	12.12	45.99	12.97	51.30	13.32	31.44
Clear flour	12.88	21.23	13.01	17.70	[3] 13.22	41.83
Low grade flour	12.30	3.54	12.39	3.90	.....	.....
Red dog	.....	.....	11.70	1.00	.....	.....
White shorts	[1] 10.40	3.86	.....	.....	[1] 11.41	3.00
Brown shorts	13.28	11.26	[2] 12.28	10.80	12.15	8.23
Bran	14.24	14.12	13.95	15.30	14.19	15.50
Total	.....	100.00	.....	100.00	.....	100.00

[1] Includes red dog. [2] Includes white shorts. [3] Includes low grade flour.

PART 5.—*The calculated gain or loss in weight resulting from the addition or evaporation of moisture during the cleaning, tempering, and milling processes.*

Product and effect of treatment.	Mill No. 1.		Mill No. 2.		Mill No. 3.	
	Moisture content.	Relative[1] weight.	Moisture content.	Relative[1] weight.	Moisture content.	Relative[1] weight.
	Per cent.		*Per cent.*		*Per cent.*	
Uncleaned and untempered wheat	12.40	100.00	13.90	100.00	14.04	100.00
Cleaned and tempered wheat	16.00	104.29	13.80	99.88	14.67	100.74
Mill products	12.65	100.29	13.02	98.99	13.26	99.10
	Per cent.		*Per cent.*		*Per cent.*	
Effect of cleaning and tempering on weight of wheat	4.29 gain		0.12 loss		0.74 gain	
Effect of milling process on weight of wheat	3.84 loss		0.91 loss		1.63 loss	
Combined effect of cleaning, tempering, and milling processes on weight of untempered wheat	0.29 gain		1.01 loss		0.90 loss	

[1] Base 100.00—untempered wheat.

EFFECT OF TEMPERING UPON THE MOISTURE CONTENT OF WHEAT.

The difference between the moisture content of wheat before and after cleaning and tempering, shown in part 1 of Table II, was, in the case of mill No. 1, an increase of 3.60 per cent; mill No. 2, a decrease of 0.10 per cent; and mill No. 3, an increase of 0.63 per cent. The lack of uniformity in tempering among these mills can be accounted for partly by the fact that the wheat milled at mill No. 1 was of the dry crop of 1914, while that milled at mills Nos. 2 and 3 was of the crop of 1915 and not nearly so dry, consequently requiring the addition of a less amount of moisture in tempering.

It appears odd that in the case of one of the mills, namely, that of mill No. 2, a slight decrease should occur. However, in this particular case, the amount of water added was very slight, and, since under certain conditions the cleaning and scouring of wheat results in the evaporation of a portion of its moisture, it may have happened that the amount lost from this cause exceeded that added at the time of tempering.

DISTRIBUTION OF MOISTURE IN THE TEMPERED WHEAT KERNEL.

An examination of the data of part 2 of Table II shows that as the process of milling progressed from the breaks to the sizings and middlings reductions, and then to the tailings and low grade reductions, the moisture content of the streams of stock on the various rolls became less and less. Figure 1, which gives a graphic representation of the relative amounts of moisture present at the successive steps in the milling process indicated in this part of the table, illustrates this fact more clearly. The curves shown in this figure represent, for each mill, the differences in the moisture content of the various streams of roll stock before grinding.

An interesting point to note in this connection is that the moisture content of the second, third, and fourth break streams in the instance of mills Nos. 2 and 3 was higher than that of the wheat on the first break roll. In the part of the milling process known as the break reductions, there is a gradual reduction of the wheat kernel resulting in a more or less complete separation of the middlings or endosperm particles from the bran. This fact, considered in connection with the point mentioned above, leads to the conclusion that for the cases examined, very little of the water added in tempering penetrated farther than the outer coatings of the kernel.

It is a well-known fact that fifth and sixth break streams are composed of a greater percentage of bran than the preceding breaks, and in accordance with the conclusion just stated, should contain a correspondingly higher percentage of moisture. The results shown here, however, are of a contradictory nature. The probable explanation of this apparent inconsistency is that the loss of moisture through evaporation at the time of grinding and bolting exceeded any increase in the moisture content of such streams caused by the elimination of drier particles.

It is observed also that the roll streams containing the lesser amounts of moisture were those known as the low grades, which streams occur at the extreme end of the milling process. This low-grade stock is composed of very small bran and germ particles together with such endosperm particles as are unavoidably removed with them when the former are separated from the various streams of reduced middlings. The probable reason for their lesser moisture content is the fact that the parts of the kernel composing these streams are subjected to the grinding action of the rolls a greater number of times and, consequently, are exposed to the drying effect of the atmosphere much more than those composing the other streams.

An interesting observation in connection with the data given in parts 1 and 2 of Table II is that, in spite of the relatively great difference among the mills in the moisture content of the wheat at the

beginning of the milling process, a close similarity existed in the amounts of moisture contained in the respective sizings and middlings streams of the three mills.

LOSS OF MOISTURE DURING GRINDING.

The effect of the grinding on the moisture content of wheat and various kinds of roll stock is shown in part 2 of Table II as the differ-

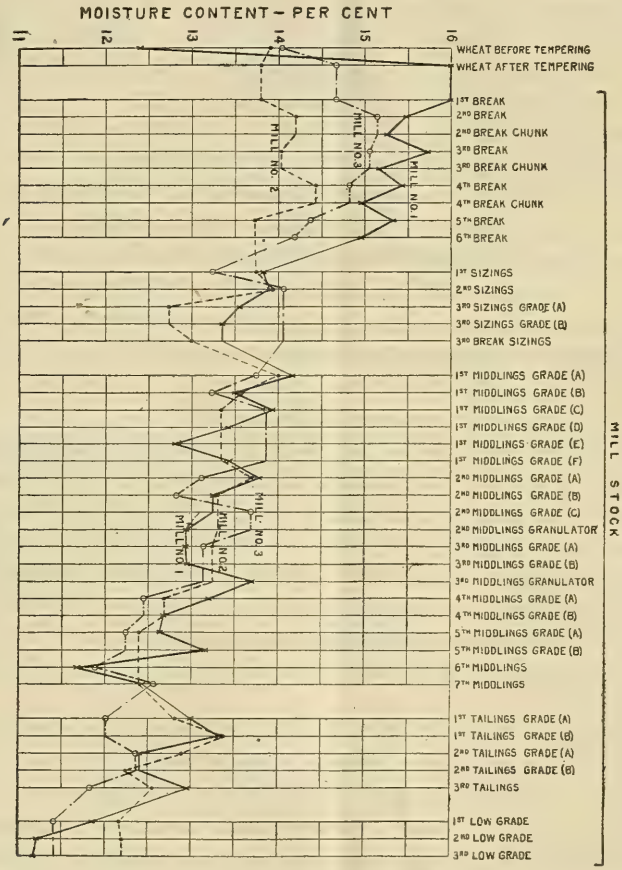

FIG. 1.—Diagram showing differences in the moisture content of streams of mill stock going to the various rolls.

ence between the moisture content of the streams before and after grinding. The average decrease for all grinding operations was 0.392 per cent for mill No. 1; 0.340 per cent for mill No. 2; and 0.370 per cent for mill No. 3. The average decrease, however, among the three mills, for that portion of the grinding operations known as the breaks, varied considerably, being 0.482 per cent for mill No. 1; 0.270 per cent for mill No. 2; and 0.135 per cent for mill No. 3. This wide range between mill No. 1 and the other mills was possibly

due to the higher moisture content of the break streams of mill No. 1. On the other hand, the average decrease for the reductions, or those grinding operations of sizings, middlings, tailings, and low grade stock was 0.367 per cent for mill No. 1; 0.358 per cent for mill No. 2; and 0.452 per cent for mill No. 3; or, in other words, was least for mill No. 1 and greatest for mill No. 3. These differences among the mills in the average decrease of moisture content resulting from grinding

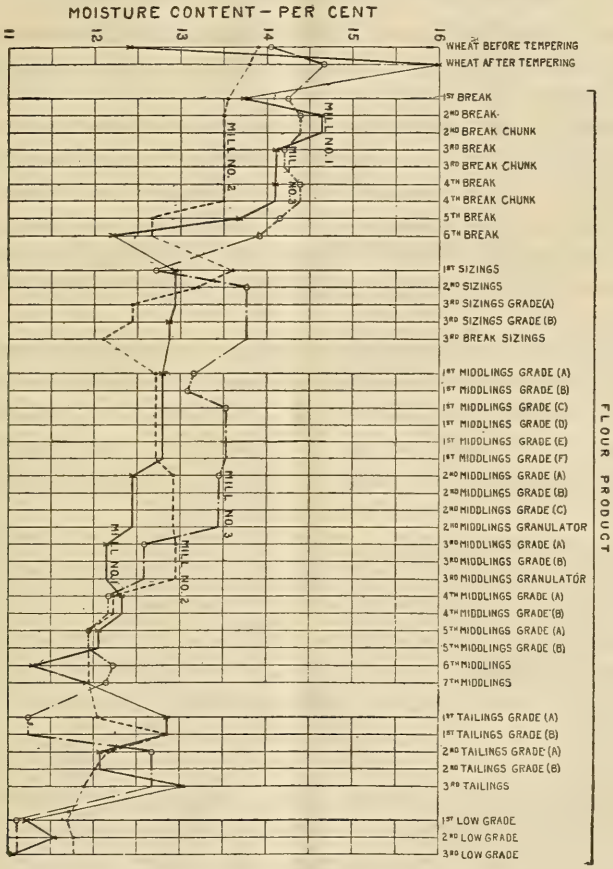

FIG. 2—Diagram showing differences in the moisture content of flour resulting from the various grinding operations.

was probably due in part to variations in methods of milling and in atmospheric conditions at the time of grinding.

Four instances are shown in which the percentage of moisture contained in the roll stream after grinding was greater than before. It is possible that in these instances the samples from which the determinations were made were not representative of the streams sampled, and, therefore, the results obtained do not represent actual conditions. The fact that three of the four instances appeared in connection with

break streams adds weight to this conclusion, especially since it is true that the streams coming from the break rolls are composed of particles differing greatly in size and character, thereby making it difficult to secure a representative sample, or to divide it, for the purpose of moisture determination, into smaller portions composed of the different sizes and character of particles in their proper proportion.

MOISTURE CONTENT OF DIFFERENT FLOUR STREAMS.

Part 3 of Table II shows the percentage of moisture contained in the flour produced by the different grinding, or reduction, operations indicated in part 2.

In practically all mills it is the practice to combine streams of small quantity and similar quality coming from different grinding operations before a separation of the flour product is made. The moisture percentages in some of the instances given here represent the moisture content of the flour product of combined streams, a fact which accounts for some of the apparent omissions and inconsistencies in the table.

Probably the most interesting thing to note from the data given in part 3, as in the case of the data of part 2, is the reduction of the moisture content of the flour streams as the milling proceeded from first break to the end of the process, the break streams being highest and the low grade streams lowest. This point is illustrated more clearly by the curves shown in figure 2.

The flour streams resulting from the break stock of mills Nos. 1 and 3 showed a considerably higher moisture content than did those from the sizings, middlings, tailings, or low grade stock. The moisture content of the break flour of mill No. 2, on the other hand, did not appreciably differ from that of the sizings and middlings flour. This may have been due to the little difference in moisture content among the break, sizings, and middlings roll streams.

Examination of parts 2 and 3 of Table II shows, except with respect to the break flour product of mills Nos. 1 and 3, a close correspondence between the moisture content of the flour product and that of the roll stream from which it was derived. The moisture content of the different break flour streams of mills Nos. 1 and 3, although higher than that of their middlings and sizings flour was, in some instances, as much as 2 per cent lower than that of the break roll streams from which they were produced.

MOISTURE CONTENT AND YIELD OF MILL PRODUCTS.

Part 4 of Table 2 shows the percentage of moisture contained in the different commercial products of each mill together with the percentage of yield of each. The milling yields given here are based upon the actual weights of the products milled during a test run made

at the time the samples were obtained. The duration of the test run was 12 hours for mills Nos. 1 and 2, and 2 hours for mill No. 3. The wide range among the mills shown here in the yields of the different flours has little general significance, because each of these mills, within certain limits, varied the quality of its flour product to meet the requirements of its trade.

It is interesting to note that the moisture content of the patent flour of each mill was lower than that of the untempered wheat. This is even true in the case of mill No. 1, where the increase in moisture content during tempering was as great as 3.60 per cent. This fact further substantiates the conclusion already expressed that very little of the water added to the wheat during tempering penetrated deeper than the pericarp, or branny portion of the kernel.

The moisture content of the clear flour of mills Nos. 1 and 2 is shown to be slightly higher than that of the patent flour. For mill No. 3 the clear and low grade flours were combined; consequently, the moisture content given is not representative of each separately, but is, no doubt, too low for the former and too high for the latter.

Another interesting observation is that the low grade flour, red dog, and white shorts had a lower moisture content than the brown shorts or bran. This further indicates that little of the moisture added during tempering penetrated beyond the pericarp.

GAINS AND LOSSES IN WEIGHT EFFECTED BY CHANGE IN MOISTURE CONTENT INCIDENT TO TEMPERING AND MILLING.

In part 5 of Table II are shown the percentages of weight gained or lost by the addition or evaporation of moisture incident to the tempering and milling processes. The calculation of the relative amounts gained or lost is based on differences in moisture content of the untempered wheat, the tempered wheat, and the mill products. The average moisture content given here of the mill products is calculated from the moisture content and milling yield of the products referred to in part 4.

The change in weight resulting from the change in moisture content of the wheat during cleaning and tempering shows for mill No. 1 a gain of 4.29 per cent, for mill No. 2 a loss of 0.12 per cent, and for mill No. 3 a gain of 0.74 per cent.

The loss in weight of the cleaned and tempered wheat through evaporation of moisture during the process of milling, is shown to have been 3.84 per cent for mill No. 1, 0.91 per cent for mill No. 2, and 1.63 per cent for mill No. 3. These losses show a correspondence to the gains resulting from tempering in that the mill showing the greatest gain during tempering had the greatest loss during milling, and the mill showing the least gain during tempering had the least loss during milling.

The net change in weight due to change in moisture content from the beginning of the tempering process to the end of the milling process was, for mill No. 1, a gain of 0.29 per cent; for mill No. 2, a loss of 1.01 per cent; and for mill No. 3, a loss of 0.90 per cent. From a comparison of all the results given in part 5, it may be concluded that the amount of water added in tempering compensated for the evaporation of moisture during milling only in the case of mill No. 1.

Whether or not the calculated gains and losses given here for each of the three mills agree with the gains and losses ascertained from an actual weighing of the wheat and the products milled therefrom is not known except in the instance of mill No. 1. Calculations made from the daily and weekly reports of this mill giving the scale readings of the wheat before cleaning and tempering, after tempering, and of the products from the packers showed approximately the same results as those given in the table.

In the actual milling of wheat on a commercial scale, the correct percentage of gain or loss resulting from the addition or evaporation of moisture during the tempering and milling processes, whether based on differences in moisture content or in weight, can not be obtained exactly, for the reason that the moisture content is affected by certain variable conditions, and calculations which would be based upon any samples obtained would be incorrect to the extent of their variation from the true average condition. Both the moisture content of the untempered wheat, and the amount of water added during tempering are also likely to vary from time to time, resulting in a proportionate variation in the moisture content of the tempered wheat. Furthermore, any change in the adjustment of the rolls and other machines or in atmospheric conditions may cause a slight variation in the evaporation of moisture and the milling yield of the different products. All such variations necessarily affect the accuracy of the results.

SUMMARY OF RESULTS.

(1) The decrease in the moisture content of the various roll streams from the head to the tail of the milling process was closely related to the amount of water added to the wheat during tempering.

(2) It appeared that very little of the moisture added to the wheat during tempering penetrated farther than the pericarp or outer coatings of the kernel.

(3) The moisture content of the better grades of flour milled, irrespective of the amount of water added during tempering, closely corresponded to the percentage of moisture contained in the untempered wheat.

(4) The amount of water added in tempering compensated for the evaporation of moisture during milling only in the case of one of three mills examined.

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NOTES ON GRAIN PRESSURES IN STORAGE BINS.

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CONTENTS.

INTRODUCTION.

The formula derived by Janssen for the determination of the vertical and lateral pressures of grain in bins is one commonly used by grain elevator engineers. Most engineers, in their calculations, have also made use of a table of values similar to the one here given, by means of which the unit pressures are more quickly and easily determined (see Table 1). In this bulletin are given rules for the more advantageous application of this table, together with additional tables and graphical charts which should further facilitate the designing of grain bins.

JANSSEN'S FORMULA.[1]

In Janssen's formula the following nomenclature is used:

A = area of bin in square feet.

P = perimeter of bin in feet.

R = hydraulic radius of bin $= \frac{A}{P}$

Note.—This bulletin is of interest to engineers, particularly those having occasion to design grain storage bins.

[1] For the derivation of Janssen's formula together with descriptions and results of different experiments to determine values for the coefficient of friction of grain on bin walls and the ratio of the lateral to the vertical pressure at any point, see Ketchum, Milo S., The design of walls, bins, and grain elevators, 2d ed., New York, 1911.

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D = diameter of bin or diameter of inscribed circle in feet.
H = height in feet of grain above point in question.
μ' = coefficient of friction of grain on bin walls.
W = weight of grain in pounds per cubic foot.
V = vertical pressure of grain at depth H in pounds per square foot.
L = lateral pressure of grain at depth H in pounds per square foot.
$k = \frac{L}{V}$ = ratio of lateral to vertical pressure.
e = base of Naperian logarithms.

NOTE.—Both V and L are assumed to be constant at all points on a horizontal plane.

$$V = \frac{R \times W}{k \times \mu'}\left(1 - \frac{1}{e^{\frac{k \times \mu' \times H}{R}}}\right)$$

For round and for square bins or other bins of the form of a regular polygon, the hydraulic radius $\frac{A}{P}$ is equal to $\frac{D}{4}$ and the formula becomes

$$V = \frac{D \times W}{4 \times k \times \mu'}\left(1 - \frac{1}{e^{\frac{4 \times k \times \mu' H}{D}}}\right)$$

$$L = kV$$

VALUES OF μ' AND k.

Numerous experiments have been made with various grains in bins constructed of different materials to determine values for the factors μ' and k. The results of several of these experiments are given in the appendix.

PRESSURE FACTORS FOR WHEAT IN ROUND OR OTHER REGULAR CONCRETE BINS.

By taking μ' equal to 0.4167, an average value for wheat on concrete, and k equal to 0.6, an accepted value for wheat in concrete bins, the product $4 \times k \times \mu'$ becomes equal to 1.0, and with W equal to 50 pounds, the formula simplifies to

$$V = 50 \times D\left(1 - \frac{1}{e^{\frac{H}{D}}}\right)$$

$$\text{or } \frac{V}{D} = 50 \quad \left(1 - \frac{1}{e^{\frac{H}{D}}}\right)$$

$$\text{and } \frac{L}{D} = 0.6\frac{V}{D}$$

Values for the pressure factors $\frac{V}{D}$ and $\frac{L}{D}$ may be tabulated for different values of $\frac{H}{D}$. (See Table 1.)

TABLE 1.—*Pressure factors for wheat in round or other regular concrete bins.*

(Pounds per square foot in diameter.)

$\frac{H}{D}$	$\frac{V}{D}$	$\frac{L}{D}$	$\frac{H}{D}$	$\frac{V}{D}$	$\frac{L}{D}$
0.1	4.76	2.86	2.3	44.97	26.98
.2	9.06	5.44	2.4	45.46	27.28
.3	12.96	7.77	2.5	45.89	27.53
.4	16.48	9.88	2.6	46.29	27.77
.5	19.67	11.80	2.7	46.64	27.98
.6	22.56	13.53	2.8	46.96	28.18
.7	25.17	15.10	2.9	47.25	28.34
.8	27.53	16.52	3.0	47.51	28.50
.9	29.67	17.80	3.1	47.75	28.64
1.0	31.61	18.96	3.2	47.96	28.77
1.1	33.36	20.01	3.3	48.16	28.89
1.2	34.94	20.96	3.4	48.33	28.99
1.3	36.37	21.82	3.5	48.49	29.09
1.4	37.67	22.60	3.6	48.63	29.18
1.5	38.84	23.30	3.7	48.76	29.26
1.6	39.90	23.94	3.8	48.88	29.33
1.7	40.87	24.52	3.9	48.99	29.39
1.8	41.74	25.04	4.0	49.08	29.45
1.9	42.52	25.51	5.0	49.66	29.79
2.0	43.23	25.94	6.0	49.88	29.92
2.1	43.88	26.32	7.0	49.95	29.97
2.2	44.46	26.67	10.0	49.99	29.99

For use of this table see example 1, page 10.

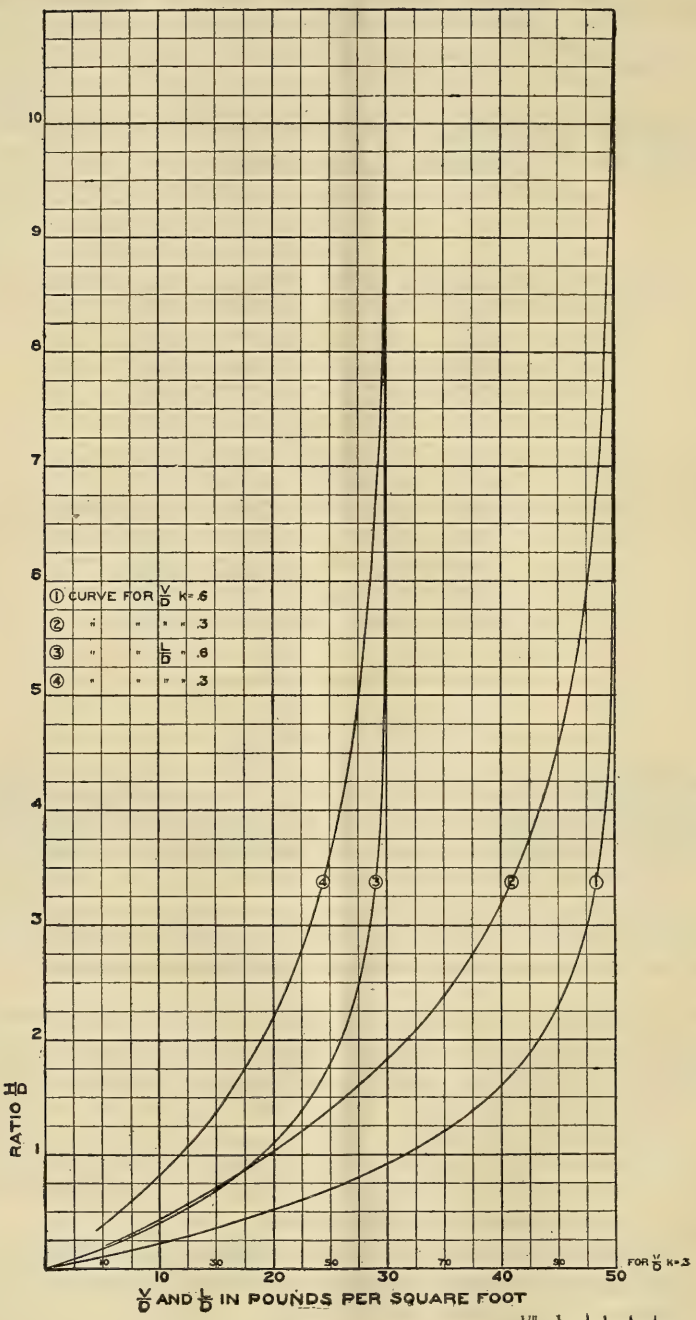
EXPLANATION OF PLATE I.

The values given by Table 1 are plotted on Plate I, curve 1, showing the variation of vertical pressures, and curve 3, the variation of lateral pressures. Similar curves, 2 and 4, are plotted to show the variation of pressures when k is assumed equal to 0.3. It is to be noted that values for $\frac{V}{D}$ when $k=0.3$, are to be taken from the upper line of figures, curve 2 being drawn to a horizontal scale of one-half the scale of curve 1. Curve 4, however, showing the variation of values for $\frac{L}{D}$ when $k=0.3$ is drawn to the same scale as curves 3 and 1, and the values are to be read from the lower line of figures.

It is evident from the curves that:

A. After a height is reached of 3 to 4 times the diameter there is but little increase in the unit pressures, the additional weight going directly into the walls as a vertical load.

B. There is considerable difference in the values obtained for the vertical pressures for different assumed values of k; the lateral pressures, however, are affected very little.


① CURVE FOR V/D K=.6
② " " " " .3
③ " " L/D " .6
④ " " " " .3
RATIO H/D
V/D AND L/D IN POUNDS PER SQUARE FOOT
FOR V/D K=.3
Wilson James Larkin August 10, 1918

(*a*) In very shallow bins there is little difference in the vertical pressures obtained for different values of k, while as the bins become deeper $\frac{V}{D}$ for $k=0.3$ rapidly approaches a value twice as great as for $k=0.6$.

(*b*) In snallow bins the value obtained for the lateral pressures for $k=0.3$ are about one-third less than for $k=0.6$, but as the bins become deeper $\frac{L}{D}$ for $k=0.3$ rapidly approaches the same value as for $k=0.6$.

(*c*) As most grain bins are deep bins, the best general value for k is 0.6. This gives the maximum value for the lateral pressure and also gives the maximum value for the vertical load carried by the bin walls. It is very essential that the determination of the bearing area of the walls and in some cases the design of the foundation, be based on maximum values for the vertical wall loads.

Possibly it would seem best in designing the bin bottom to use the maximum values for the vertical pressure obtained when k is taken equal to 0.3. Most designers, however, work on the assumption that 0.6 is more nearly the correct value for k than 0.3 and use the lesser values for the vertical pressures.

DETERMINATION OF UNIT PRESSURES IN RECTANGULAR OR OTHER IRREGULAR BINS.

Accepting Janssen's formula as a general one applying to all forms of bins, we can conclude that the unit pressures in any bin are equal to those in any other bin of the same hydraulic radius. For round or other regular bins $4\times R=D$ where R = hydraulic radius. Then the hydraulic radius of any bin multiplied by 4 will give a value equal to the diameter of the equivalent round bin and the pressure factors may be obtained from Table 1.

DETERMINATION OF UNIT PRESSURE FOR VARIOUS GRAINS IN BINS OF DIFFERENT MATERIALS.

Tables 1 and 2 were developed on the assumption that for wheat in concrete bins k equals 0.6 and μ' equals 0.4167. The product $4\times k\times\mu'$ thus becomes equal to 1 and W was taken equal to 50 pounds.

These tables may be readily used to figure the unit pressures and reinforcing in any bin for any assumed value of k and μ', by computing a compensated value for D which may be designated by D'.

Original formula for regular bins:

$$V=\frac{D\times W}{4\times k\times\mu'}\left(1-\frac{1}{e^{\frac{4\times k\times\mu'\times H}{D}}}\right)$$

If $4 \times k \times \mu' = N$, not equal to 1,

$$V = \frac{D}{N} \times W \left(1 - \frac{1}{e^{\frac{H}{\frac{D}{N}}}} \right)$$

Let $\frac{D}{N} = D'$, then the formula becomes,

$$V = D' \times W \left(1 - \frac{1}{e^{\frac{H}{D'}}} \right)$$

$$\frac{V}{D'} = W \left(1 - \frac{1}{e^{\frac{H}{D'}}} \right)$$

$$L = kV$$

For values of W other than 50 pounds V and L may be determined by direct proportion. (See Example 4, page 14.)

HORIZONTAL REINFORCING FOR CYLINDRICAL CONCRETE BINS.

In a cylindrical tank the total pressure on any diameter for 1 foot in height is equal to the lateral pressure per square foot at that level times the diameter in feet, or $L \times D$. This pressure, tending to burst the tank, produces tension in the walls, and, since two cross sections of the wall are cut by each diameter, the total tensile stress on each cross section of the wall for 1 foot in height is equal to $\frac{L \times D}{2}$. Assuming that all of the tensile stress is taken by the steel reinforcing, and indicating the allowable unit stress in the steel by f_s, the cross-sectional area of steel required in square inches per foot in height at that level is given by the formula:

$$a = \frac{L \times D}{2 \times f_s}$$

This formula may be written,

$$\frac{a}{D^2} = \frac{L}{D} \times \frac{1}{2 \times f_s}$$

Since the pressure factor $\frac{L}{D}$ is determined by $\frac{H}{D}$, we can tabulate values for the steel factors $\frac{a}{D^2}$ for different values of $\frac{H}{D}$. (See Table 2.)

TABLE 2.—*Steel factors for horizontal reinforcing in cylindrical concrete tanks.*

[Areas of steel per foot in height per diameter squared.]

$\frac{H}{D}$	$\frac{a}{D^2}$			$\frac{H}{D}$	$\frac{a}{D^2}$		
	$f_s=16000$	$f_s=18000$	$f_s=20000$		$f_s=16000$	$f_s=18000$	$f_s=20000$
0.1	0.000089	0.000079	0.000072	2.2	0.000843	0.000749	0.000675
.2	170	151	136	2.4	853	758	682
.3	243	216	194	2.5	860	765	688
.4	309	274	247	2.6	868	771	694
.5	369	328	295	2.7	874	777	700
.6	423	376	338	2.8	881	783	705
.7	472	419	378	2.9	886	787	709
.8	516	459	413	3.0	.000891	.000792	.000713
.9	556	494	445	3.1	895	795	716
1.0	.000593	.000527	.000474	3.2	899	799	719
1.1	625	556	500	3.3	903	802	722
1.2	655	582	524	3.4	906	805	725
1.3	682	606	546	3.5	909	808	727
1.4	706	628	565	3.6	912	810	729
1.5	728	647	583	3.7	914	813	731
1.6	748	665	599	3.8	917	815	733
1.7	760	675	608	3.9	918	816	735
1.8	783	695	626	4.0	.000920	.000818	.000736
1.9	797	708	638	5.0	931	827	745
2.0	.000811	.000720	.000649	6.0	935	831	748
2.1	823	731	658	7.0	936	832	749
2.2	833	741	667	10.0	.000937	.000833	.000750

[For use of this table, see Example 2, page 11.

HORIZONTAL REINFORCING FOR STRAIGHT WALLS OF CONCRETE BINS.

In all bins other than cylindrical tanks the walls are designed as slabs supporting at any given level a uniform load equal to the lateral grain pressure at that point.

Tables 3*a*, 3*b*, and 3*c*, for different allowable stresses in steel and concrete, give the maximum resisting moments and the steel areas required for different effective thicknesses of walls. Also, for different conditions of continuity, constants are listed for determining the heights at which the size or spacing of the bars may be changed.

In the following, the standard nomenclature for reinforced concrete is used also: Let—

L = lateral pressure of the grain in pounds per square foot.

l = span of wall in feet.

t = thickness of wall in inches.

e = thickness of concrete outside of steel in inches.

$d = t - e$ = effective depth to steel in inches.

a = area of steel per foot in height in square inches.

M = bending moment or resisting moment in inch pounds.

m = coefficient of continuity for figuring bending moment.

= 8 for simple spans $M = \frac{L \times l^2 \times 12}{8}$

= 10 for end spans—partial continuity $M = \frac{L \times l^2 \times 12}{10}$

= 12 for intermediate spans—full continuity $M = \frac{L \times l^2 \times 12}{12}$

For any effective depth to steel the maximum resisting moment, which is developed when the steel and concrete are simultaneously stressed to the assumed allowable values for f_s and f_c, is given by the equation:

$$M = f_s jpbd^2$$

For selected values of f_s, f_c, and n and for $b=12$, the product $f_s jpb$ is a constant and

$$M = Cd^2$$

The area of steel required is given by the equation

$$a = pbd$$

The area of steel may also be figured from the equation

$$a = \frac{M}{f_s \times j \times d} \quad \text{or}$$

$$a = \frac{L \times l^2 \times 12}{m \times f_s \times j \times d}$$

For selected values of f_s, f_c, and n and for different values of m and d the product $\frac{m \times f_s \times j \times d}{12}$ is a constant which may be designated by R. Then

$$a = \frac{L \times l^2}{R}$$

$$L = \frac{a \times R}{l^2}$$

The thickness of the wall is determined by the bending moment at the bottom, and, as this thickness is maintained for the full height, it will be greater in the upper portion of the wall than required to develop the assumed stresses. The stress in the concrete will decrease from bottom to top and, as the thickness of the wall is usually selected in even inches, the stress at the bottom will generally be less than the assumed allowable value. In some cases, however, a wall thickness may be chosen slightly less than actually required for the moment at the bottom, in which case the stress in the concrete at that level will exceed the assumed value.

With each change from the bottom to the top in the spacing or size of the reinforcing bars, there is a decrease in the value for the percentage of steel, and, assuming n to be constant, a corresponding increase in the value for j. Therefore, the results obtained by use of the formula $L = \frac{a \times R}{l^2}$, for which R has been computed for a constant value of j, are not absolutely correct. In any case, however, the error is small and, moreover, is on the safe side, because, if the increased value for j was used, slightly larger values for L, the allowable pressure for a given steel area, would be obtained.

TABLE 3A.—*Maximum resisting moments developed and steel areas required for different thicknesses of straight bin walls per foot in height.*

$n=15$

$f_s=16000$ $f_c=650$ $p=0.0077$ $k=0.378$ $j=0.874$ $C=b\,f_s\,p\,j=1292$ $p\,b=0.0924$

Thickness of wall in inches. t	Concrete outside of steel in inches. e	Depth to steel in inches. d	Maximum resisting moment in inch pounds. $M=1292d^2$	Required steel area in square inches. $a=0.0924d$	Values for $R=\frac{m\,j\,f_s\,d}{12}=1165\,m\,d$		
					$m=8$	$m=10$	$m=12$
4	1	3	11600	0.277	28000	35000	42000
5	1	4	20700	.370	37300	46600	56000
6	1¼	4¾	29200	.439	44300	55300	66400
6	1	5	32300	.462	46600	58300	70000
7	1¼	5¾	42700	.531	53700	67000	80400
7	1	6	46500	.554	56000	70000	83900
8	1½	6½	54600	.600	60600	75700	90900
8	1¼	6¾	58900	.624	62900	78600	94400
9	1½	7½	72700	.693	70000	87400	104900
9	1¼	7¾	77600	.716	72200	90300	108400

TABLE 3B.—*Maximum resisting moments developed and steel areas required for different thicknesses of straight bin walls per foot in height.*

$n=15$

$f_s=18000$ $f_c=700$ $p=0.0072$ $k=0.368$ $j=0.877$ $C=b\,f_s\,p\,j=1364$ $p\,b=0.0864$

Thickness of wall in inches. t	Concrete outside of steel in inches. e	Depth to steel in inches. d	Maximum resisting moment in inch pounds. $M=1364d^2$	Required steel area in square inches. $a=0.0864d$	Values for $R=\frac{m\,j\,f_s\,d}{12}=1315\,m\,d$		
					$m=8$	$m=10$	$m=12$
4	1	3	12300	0.259	31600	39400	47300
5	1	4	21800	.346	42100	52600	63100
6	1¼	4¾	30800	.410	50000	62500	75000
6	1	5	34100	.432	52600	65800	78900
7	1¼	5¾	45100	.497	60500	75600	90700
7	1	6	49100	.518	63100	78900	94700
8	1½	6½	57600	.561	68400	85500	102600
8	1¼	6¾	62140	.583	71000	88800	106500
9	1½	7½	76700	.648	78900	98600	118400
9	1¼	7¾	81920	.670	81500	101900	122300

TABLE 3C.—*Maximum resisting moments developed and steel areas required for different thicknesses of straight bin walls per foot in height.*

$n=15$

$f_s=20000$ $f_c=700$ $p=0.0060$ $k=0.344$ $j=0.885$ $C=b\,f_s\,p\,j=1274$ $p\,b=0.072$

Thickness of wall in inches. t	Concrete outside of steel in inches. e	Depth to steel in inches. d	Maximum resisting moment in inch pounds. $M=1274d^2$	Required steel area in square inches. $a=0.072d$	Values for $R=\frac{m\,j\,f_s\,d}{12}=1475\,m\,d$		
					$m=8$	$m=10$	$m=12$
4	1	3	11500	0.216	35400	44300	53100
5	1	4	20400	.288	47200	59000	70800
6	1¼	4¾	28800	.342	56100	70000	84100
6	1	5	31900	.360	59000	73800	88500
7	1¼	5¾	42100	.414	67900	84800	101700
7	1	6	45900	.432	70800	88500	106200
8	1½	6½	53900	.468	76700	95900	115000
8	1¼	6¾	58000	.486	79700	99600	119400
9	1½	7½	71700	.540	88500	110600	132750
9	1¼	7¾	76600	.558	91500	114300	137150

DETERMINATION OF VERTICAL AND LATERAL PRESSURES IN GRAIN BINS WITH HORIZONTAL REINFORCING FOR CYLINDRICAL CONCRETE TANKS BY MEANS OF PLATE II.

By means of the four curves on the chart in Plate II, which have been plotted from values given by Tables 1 and 2, the vertical and lateral unit pressures may be determined for any bin, and in the case of cylindrical concrete tanks the size and spacing of the horizontal reinforcing may be obtained without the need of any calculations.

The manner in which this chart may be used can best be explained by means of several examples, which will be first solved mathematically, using the values given by Tables 1 and 2, and then directly from the chart.

EXAMPLES SHOWING USE OF PLATE II.

EXAMPLE 1.

Required: The vertical and lateral unit pressures at the bottom in a round or square bin 15 feet in diameter and 75 feet in height.

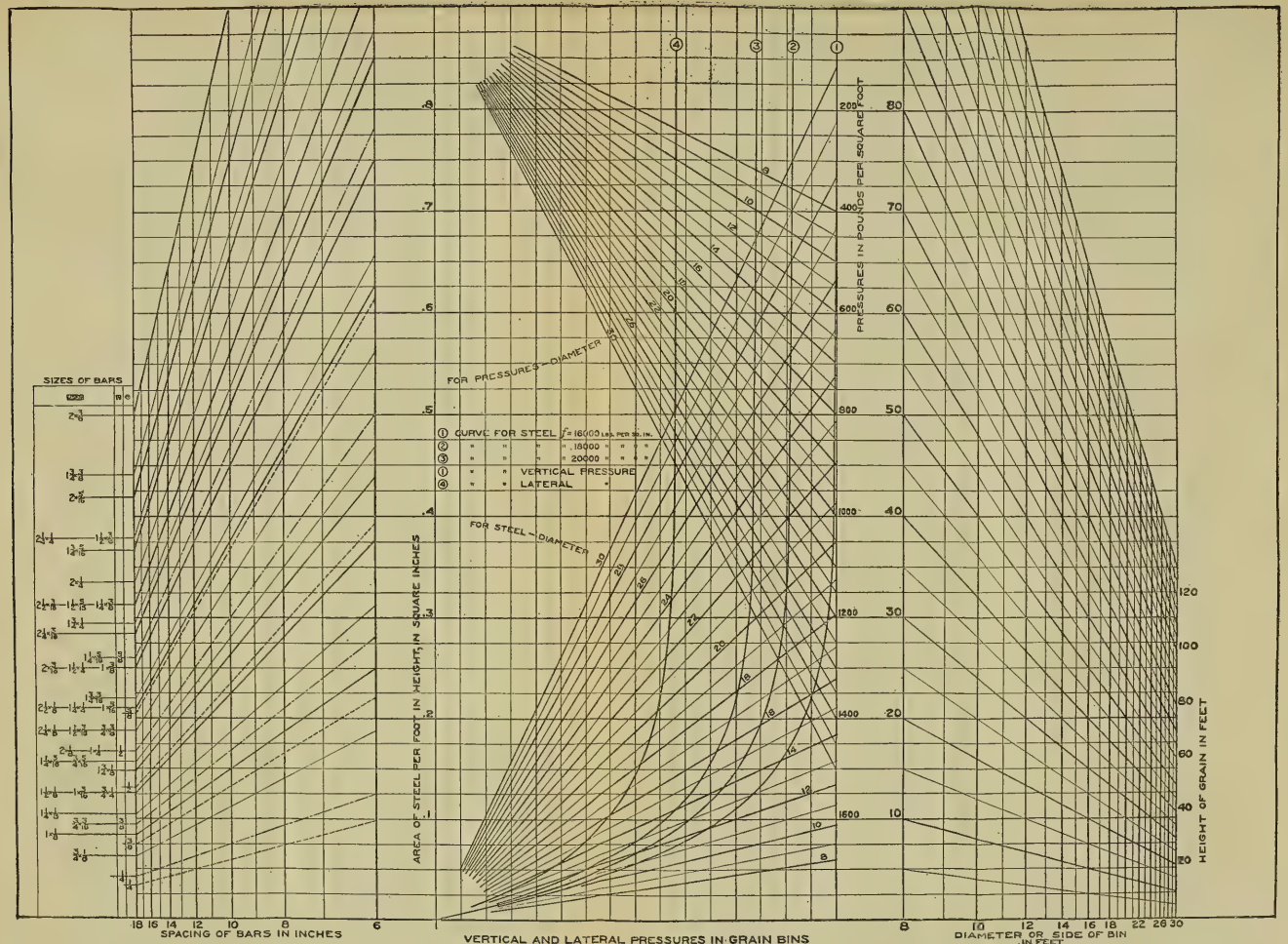
$\frac{H}{D}=\frac{75}{15}=5$

From Table 1: For $\frac{H}{D}=5$

$\frac{V}{D}=49.66$ and $V=15\times 49.66=745$ pounds per square foot.

$\frac{L}{D}=29.79$ and $L=15\times 29.79=447$ pounds per square foot.

From Plate II: Follow the vertical line at the right-hand side for diameter 15 feet upward to its intersection with the oblique line representing 75 feet for the height of the grain. This will be found to be on the heavy horizontal line fourth from the bottom of the page. Follow this horizontal line to the left to its intersection with curve 1. Project from this intersection vertically to the line for diameter 15 feet of the set of radial lines for pressures. This last intersection will be found to be horizontally opposite a point on the scale for pressures a little above the line for 750 or about 745 pounds per square foot, which equals the unit vertical pressure. Returning to the fourth heavy line from the bottom, continue to the left to its intersection with curve 4, again project vertically to radial line 15 for pressures, then horizontally to the right to a little above the line for 450 or about 445 pounds per square foot, which equals the unit lateral pressure.



VERTICAL AND LATERAL PRESSURES IN GRAIN BINS
WITH
HORIZONTAL REINFORCING FOR CYLINDRICAL CONCRETE TANKS

William James Larkin August 10, 1916

EXAMPLE 2.

Required: The area of steel in square inches per foot in height for horizontal reinforcing for a cylindrical concrete tank 25 feet in diameter and 100 feet in height at four levels, (1) at bottom, (2) at height of 25 feet, (3) at height of 50 feet, (4) at height of 75 feet. ($f_s = 18000$).

From Table 2:

At bottom $\frac{H}{D} = \frac{100}{25} = 4$; $\frac{A}{D^2} = 0.000818$ $A = 0.511$ sq. in.

At 25′ 0″ $\frac{H}{D} = \frac{75}{25} = 3$; $\frac{A}{D^2} = 0.000792$ $A = 0.495$ sq. in.

At 50′ 0″ $\frac{H}{D} = \frac{50}{25} = 2$; $\frac{A}{D^2} = 0.000720$ $A = 0.450$ sq. in.

At 75′ 0″ $\frac{H}{D} = \frac{25}{25} = 1$; $\frac{A}{D^2} = 0.000527$ $A = 0.329$ sq. in.

From Plate II: As before, follow the vertical line at the right-hand side for diameter 25 feet upward to its intersection with the oblique line representing 100 feet for the height of the grain. From this intersection project horizontally to curve 2 for $f_s = 18000$, then vertically to the line for diameter 25 feet of the set of radial lines for steel. This last intersection will be found to be horizontally opposite a point on the scale for steel areas a little above 0.5 or about 0.51 square inch, which equals area of steel per foot in height at the bottom.

In the same manner by starting in turn with the intersections of the vertical line for 25-foot diameter with the oblique lines for 75 feet[1] height of grain, 50 feet height of grain, 25 feet height of grain, the steel areas may be determined for these levels.

The left-hand section of the plate provides a means of determining the spacing of any size bar there listed to give a required area of steel per foot in height.

Any horizontal line through a required steel area will intersect the oblique line for any chosen size bar on the vertical line giving its required spacing.

For the present example, by reading on the horizontal line through 0.51, it will be found that any of the following combinations of bars and spacings will give the required area of steel at the bottom of the tanks:

$\frac{5}{8}''$ rounds at ..... 7″ on center.
$2\frac{1}{2}''$ by $\frac{1}{8}''$ or 1″ by $\frac{5}{16}''$ flats at ..... 7″ on center.
2″ by $\frac{3}{16}''$ or $1\frac{1}{2}''$ by $\frac{1}{4}''$ or 1″ by $\frac{3}{8}''$ flats at ..... 9″ on center.
$\frac{5}{8}''$ squares at ..... 9″ on center.
$2\frac{1}{4}''$ by $\frac{3}{16}''$ flats at ..... 10″ on center.
$2\frac{1}{2}''$ by $\frac{3}{16}''$ or $1\frac{1}{2}''$ by $\frac{5}{16}''$ or $1\frac{1}{4}''$ by $\frac{3}{8}''$ flats at ..... 11″ on center.

[1] Height of grain equals distance from level of reinforcement to top of grain.

In determining what reinforcing will be used for any tank for its full height we can proceed in three ways to allow for the decrease from bottom to top in the steel area required:

A. Fix a uniform spacing, and use decreasing sizes of bars.

B. Select one size bar and increase its spacing.

C. A combination of the first and second ways.

In any case, having determined the size and spacing of the steel at the bottom, the levels at which the succeeding changes in bar sizes or spacings may be made can be obtained from the chart by methods the reverse of those already outlined. In the present example, if we select $1\frac{1}{2}$ by $\frac{1}{4}$ inch bar, 9 inches on center, as the reinforcing at the bottom, we can proceed as follows:

Follow the diagonal line for $1\frac{1}{2}$ by $\frac{1}{4}$ inch bar down from its intersection with the horizontal line for 0.51 square inch of steel, which gave a spacing of 9 inches, to its intersection with the vertical line for 10-inch spacing; project horizontally from this intersection to radial line 25 for diameters for steel, then vertically to curve 2, again horizontally to the intersection with the vertical line for 25 feet diameter at the right-hand side of the page. This intersection will be found to be on the diagonal line for 50 feet height of grain; 50 feet from the top, therefore, we can change the spacing from 9 inches to 10 inches.

Starting from the intersection of the diagonal line for $1\frac{1}{2}$ by $\frac{1}{4}$ inch bars with the vertical line for 12-inch spacings, we find in the same manner that at the height of 32 feet from the top we can increase the spacing from 10 inches to 12 inches.

We can now either continue to increase the spacing or maintain a constant spacing of 12 inches and change the size of the bar. Selecting 1 by $\frac{1}{4}$ inch as the next size bar, proceed as before from the intersection of its diagonal line with the 12-inch spacing line, and we find that at a distance of 16 feet from the top this size bar can be substituted for the $1\frac{1}{4}$ by $\frac{1}{4}$ inch. In the same manner we will find that 1 by $\frac{1}{8}$ inch bars at 12 inches on center may be used for the last 9 feet.

EXAMPLE 3.

Required: Horizontal reinforcing for the full height in a wall of a concrete bin 10 feet by 10 feet by 60 feet in height ($f_s = 16000, f_c = 650$, $n = 15$, and, for an intermediate span, $m = 12$).

From Plate II: L, the unit lateral pressure at the bottom, $= 300$ pounds.

From Table 1: For $\frac{H}{D} = \frac{60}{10} = 6$, $\frac{L}{D} = 29.92, L = 29.92 \times 10 = 300$ pounds.

$$M = \frac{300 \times 10 \times 10 \times 12}{12} = 30{,}000 \text{ inch-pounds.}$$

From Table 3a: A wall 6 inches thick with a depth to steel of 5 inches has a resisting moment of 32,300 inch-pounds, requiring 0.462 square inch of steel per foot in height, which is slightly greater than actually required.

Using the formula $a=\frac{L\times l^2}{R}$

$$\text{we have, } a=\frac{300\times 10\times 10}{70000}=0.43 \text{ square inch.}$$

given by $\frac{5}{8}''$ rounds $8\frac{1}{2}''$ on center.

If it is desirable to have the bars spaced in even inches, we can increase the spacing to 9 inches and investigate to determine the corresponding stresses in steel and concrete.

The area of $\frac{5}{8}''$ rounds $9''$ on center equals 0.41 square inch.

$$p=\frac{0.41}{60}=0.0068.$$

for $p=0.0068$ and $n=15$, $k=0.361$, and $j=0.879$.

$$f_s=\frac{M}{a\times j\times d}=\frac{30000}{0.41\times 0.879\times 5}=16640 \text{ pounds.}$$

$$f_c=\frac{2\times f_s\times p}{k}=\frac{2\times 16640\times 0.0068}{0.361}=630 \text{ pounds.}$$

The stress in the concrete is less than the allowable assumed and the stress in the steel is not excessive.

To find the height at which the spacing may be increased to 10 inches: The area of $\frac{5}{8}''$ rounds $10''$ on center equals 0.37 square inches.

Using the formula $L=\frac{a\times R}{l^2}$

$$\text{we have } L=\frac{0.37\times 70000}{10\times 10}=0.37\times 700=259$$

$$\frac{L}{D}=\frac{259}{10}=25.9, \text{ for which } \frac{H}{D}=2 \text{ (see Table 1).}$$

H, then, is equal to 20, and at a distance of 20 feet from the top we can increase the spacing of the bars to 10 inches.

The area of $\frac{5''}{8}$ rounds $12''$ on center equals 0.31 square inch.

$$L=0.31\times 700=217$$

$$\frac{L}{D}=\frac{217}{10}=21.7, \text{ for which } \frac{H}{D}=1.3.$$

At a distance of 13 feet from the top we can increase the spacing to 12 inches.

The area of $\frac{1''}{2}$ rounds $12''$ on center $=0.20$ square inch.

$$L=0.20\times 700=140.$$

$$\frac{L}{D}=\frac{140}{10}=14, \text{ for which } \frac{H}{D}=0.6.$$

At a distance of 6 feet from the top we can change to $\frac{1''}{2}$ rounds 12″ on center.

EXAMPLE 4.

Required: Vertical and lateral pressure at the bottom of a rectangular bin 8 feet by 14 feet by 68 feet in height, walls to be of steel plates, bin to be used for storing barley weighing 40 pounds per cubic foot.

$$\text{Hydraulic radius} = \frac{8 \times 14}{16 + 28} = 2.55$$

Diameter of equivalent regular bin $= 4 \times 2.55 = 10.2$ feet.

For barley in a steel bin we may select for μ' a value of 0.375 and for k a value of 0.4, then

$$4 \times k \times \mu' = 4 \times 0.4 \times 0.375 = 0.60.$$

$$D' = \frac{10.20}{0.60} = 17 \text{ feet.}$$

At bottom $\frac{H}{D'} = \frac{68}{17} = 4$, for which $\frac{V}{D'} = 49.08$.

$$V = 49.08 \times 17 = 835 \text{ pounds.}$$

For $W = 40$ $V = \frac{40}{50}$ of $835 = 668$ pounds per square foot.

$$L = 0.4 \times 668 = 267 \text{ pounds per square foot.}$$

APPENDIX.

Values of μ', the coefficient of friction of grain on different substances, and of k, the ratio of the lateral to the vertical pressure of grain, as determined by the experiments of different observers are presented herewith.

Coefficients of friction of various kinds of grain on bin walls.

From Airy, Wilfred. The pressure of grain. Institution of civil engineers. Minutes of proceedings. Vol. 131, p. 347-358. London, 1898.

Kind.	Weight of cubic foot loosely filled into measure.	Coefficient of friction.				
		Grain on grain. μ	Grain on rough board. μ'	Grain on smooth board. μ'	Grain on iron. μ'	Grain on cement. μ'
	Pounds.					
Wheat	49	0.466	0.412	0.361	0.414	0.444
Barley	39	.507	.424	.325	.376	.452
Oats	28	.532	.450	.369	.412	.466
Corn	44	.521	.344	.308	.374	.423
Beans	46	.616	.435	.322	.366	.442
Peas	50	.472	.287	.268	.263	.296
Tares	49	.554	.424	.359	.364	.394
Flaxseed	41	.456	.407	.308	.339	.414

Values of μ' and k.

As compiled by Ketchum, M. S., in The design of walls, bins, and grain elevators. N. Y., 1911, p. 346 and 350, from experiments by J. Pleissner.

	μ'		k	
	Wheat.	Rye.	Wheat.	Rye.
Cribbed bin	0.43	0.54	0.4 to 0.5	0.23 to 0.32
Ringed cribbed bin	.58	.78	.4 to .5	.3 to .34
Small plank bin	.25	.37	.34 to .46	.3 to .45
Large plank bin	.45	.55	.3	.23 to .28
Reinforced concrete bin	.71	.85	.30 to .34	.3

Coefficient of friction between wheat and various materials of construction of bin walls.

From Jamieson, J. A. Grain pressures in deep bins. Canadian society of civil engineers. Transactions, 1093. Vol. 17, part 2, pp. 554–607. Montreal, 1905.

Material.	Coefficient of friction. μ'.
Wheat on wheat	0.532
Wheat on steel trough-plate bin	.468
Wheat on steel flat plate riveted to tie bars	0.375 to .400
Wheat on steel cylinders, riveted	.365 to .375
Wheat on cement concrete, smooth to rough	.400 to .425
Wheat on tile or brick, smooth to rough	.400 to .425
Wheat on cribbed wooden bins	.420 to .450

k for wheat=0.596.

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BULLETIN No. 790

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER August 6, 1919

RANGE MANAGEMENT ON THE NATIONAL FORESTS.

By JAMES T. JARDINE, *Inspector of Grazing*, and MARK ANDERSON, *Grazing Examiner*.

INTRODUCTION.

In the administration of the National Forests the aim is to convey to the greatest possible number the full benefit of all the resources which the Forests contain and at the same time to perpetuate these resources by regulating their use. Accordingly, grazing on the National Forests is regulated with the object of using the grazing resources to the fullest extent possible consistent with the protection, development, and use of other resources.

As the National Forests were established primarily for the protection and development of the Forests and the protection of the watersheds, great pains must be taken to harmonize grazing with these primary purposes. Also, as plans go forward for the development and use of new range and for more complete utilization of all unused areas within the ranges now in use, more and more care must be exercised to see that the wild life of the Forests is not unduly restricted. As long as a large portion of each Forest was unused by domestic stock the main feature of game protection was proper regulation of hunting; but with grazing reaching out to the pockets and corners, the problem of insuring forage and secluded spots for game becomes more complicated. The recreational features of the National Forests, too, are of increasing importance, and increased attention is necessary to harmonize grazing use with recreational use.

Rules governing the granting of grazing privileges and the use of National Forest lands for grazing purposes are to be found in the

NOTE.—A table of contents by headings will be found on page 97.

Use Book.[1] The administration of grazing in accordance with these rules for a period of nearly 14 years has resulted in the development of a system of range use which is accomplishing in a broad sense the aims of regulated grazing. The period has not been long enough, however, for such a system or its application to be perfected so as to secure the fullest and best use of the grazing resources consistent with the protection, development, and use of the other resources. Perfection in this respect may be approached only by continuous effort and by refinement in methods and practice based upon a more complete inventory of the resources involved and upon the results of investigation and experience extending over a great many years.

At the present time there are wide differences of opinion as to when a range is fully used and as to when grazing becomes inconsistent with the proper use or protection of other resources. Likewise, there are differences in opinion and in practice as regards the class of stock to which a range is best suited, the plan of grazing best adapted to a given range, the maintenance and improvement of the range, the periods of grazing, the grazing capacity, the management of the stock while on the range, and other phases of range management. These differences exist among forest officers as well as among the stockmen whose stock graze on the ranges, and as a consequence there are variations in the results secured on ranges within an individual forest as well as between forests and localities. Too frequently these variations are attributed to differences in local conditions and are taken as a matter of course. This is warranted to a limited degree only. Greater uniformity and a general approach to a desirable standard are both possible and necessary.

The object of this publication is to aid in bringing about uniformity in range management and a better understanding of grazing use in relation to the other uses of the National Forests. The importance of adjusting grazing so as to secure the perpetuation of the range resources and so as not to interfere with the requirements of other resources is emphasized throughout. The phases of range management which must be given proper attention are pointed out, and, as far as practicable, rules of procedure are given. Exhaustive discussion of each of the subjects taken up is not attempted. The purpose is rather to bring together in handy form sufficient information on the essential points of grazing practice to enable the reader to make practical application of the best principles of regulated grazing. Further information may be secured from the publications listed.

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[1] U. S. Forest Service. The Use Book, A Manual of Information About the National Forests. 1918.

DETERMINATION OF CLASS OF STOCK TO WHICH RANGE IS BEST SUITED.

Classification of the range to determine the areas best suited to the different classes of stock is the first important step toward the best use of the grazing resources. The classification should be based upon the character of the range, the grazing habits of the different classes of stock, and the relation of grazing to timber growth and other resources, and should be made without regard for the local needs of a given class of stock. The need for administrative discretion in the final division of the range between different classes of stock is recognized, but the importance of grazing the class of stock to which the range is best suited must not be unduly subordinated to other factors.

MAIN FACTORS DECIDING SUITABILITY OF RANGE.

The main factors which, combined, determine the class of stock for which a range is best suited are:

1. Character of forage.
2. Topography.
3. Distribution of watering places.
4. Animal pests.
5. Protection of timber growth, watersheds, and game.

CHARACTER OF FORAGE.

In general, cattle and horses use a grass range to better advantage than sheep. Sheep relish tender green foliage and the grains of many grasses, but they eat sparingly of coarse or dry grass foliage. Cattle consume a much larger proportion of the coarse grass forage. Horses, even more than cattle, prefer grass to weeds and browse.

On the whole, weeds are much more palatable to sheep than to cattle or horses. Only a small percentage of weeds are palatable to cattle, and even fewer are palatable to horses. Sheep show discrimination in their choice of weed forage, but they will eat parts or all of most weed species on closely grazed range.

Both sheep and cattle eat considerable browse; but sheep have a tendency to browse more than cattle, and more of the browse species on range lands appear to be palatable to them than to cattle. However, cattle reach higher than sheep and get more forage from high-growing browse species, such as scrub oak, service berry, and mahogany. Horses browse but little. For sheep to use brush range of large area readily the brush should be in open enough stand to enable the sheep and herders to move about through it. Sheep will gradually work their way through and fully use small areas, however dense the brush, if it is palatable, unless the area is too wet, as is sometimes the case where willow browse occurs in wet meadows. Cattle will use dense brush range, but prefer open grass range or open grass and browse range.

TOPOGRAPHY.

Cattle prefer level or rolling country. Altitude makes little difference if the stock have been raised on the range. Under necessity they will use rough range; but it is difficult to get equal distribution of cattle grazing on rough range without more watering places, salt grounds, fences, and herders than such ranges ordinarily are provided with. Further, cattle on rough, rocky range frequently become footsore, especially the bulls. As a consequence, there is danger of local overgrazing, and the number of bulls necessary for each 100 cows to keep up the calf crop is nearly double the number used on level or rolling range.

Sheep probably do best on smooth range, other things being equal; but they can readily use rough range, whether rocky or not, provided they can not roll the rocks and so long as there are no natural barriers which they can not get over or around. Altitude is not a factor, except that sheep do best where it is cool during the summer. More even distribution of grazing on rough range can be secured ordinarily with sheep than with cattle, because sheep are under full control of the herder. Cattle are difficult to control without division of the range by fences into comparatively small pastures.

Horses will readily use rugged range if raised on it, but horses raised on plains do not adjust themselves readily to rugged mountain range.

DISTRIBUTION OF WATERING PLACES.

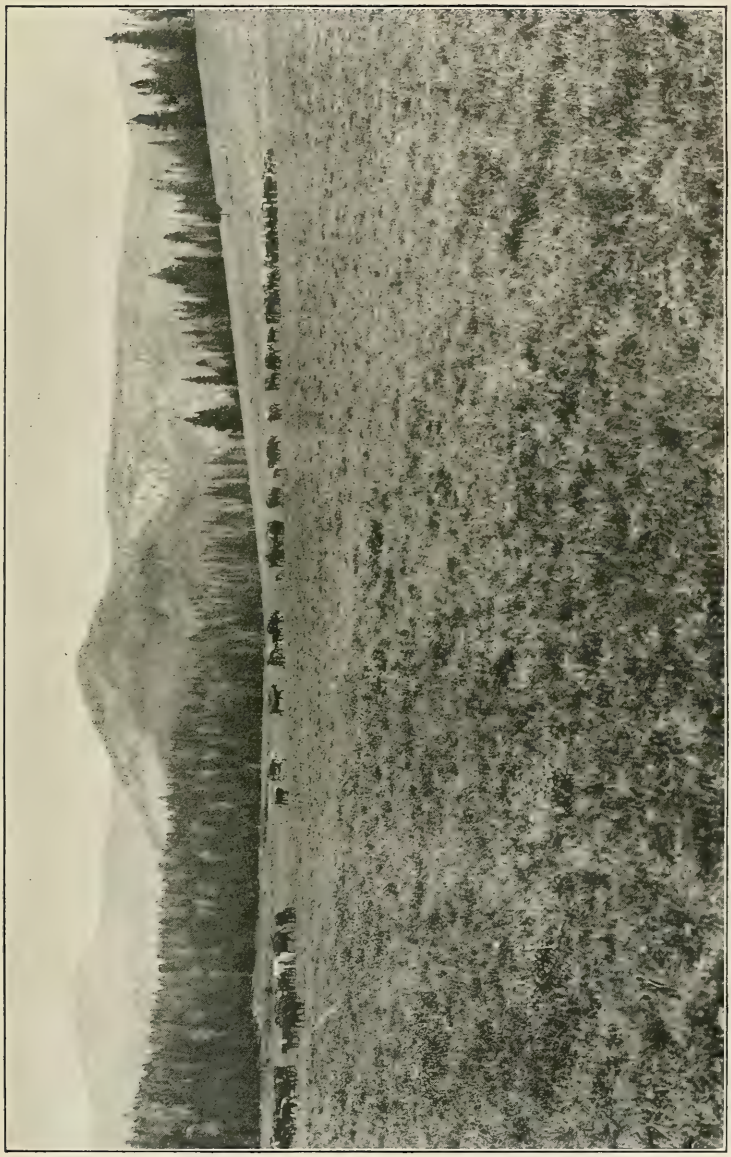
Sheep can go from several days to several weeks without drinking, depending upon the abundance of succulent weed feed, the temperature, and the amount of rain and dew. Further, if they are properly handled, they can be directed so as to graze a range of several miles' radius from one watering place without serious detriment to themserves or injury to the range.

Cattle need water oftener, at least every two days. In rough country they should not have to travel more than 1 mile, preferably half a mile, to water, and in level or rolling range not more than 2½ miles. Even with water at these distances, local overgrazing will result if the range is fully stocked with cattle.

Horses can go long distances to water and will of their own choice graze out on high open grass ridges far from watering places.

ANIMAL PESTS.

The presence of bloodsucking insects sometimes makes it impracticable to graze cattle or horses on ranges which otherwise are well suited to them. These pests are usually most numerous and most troublesome at the higher elevations. On such ranges there is usually a heavy snowfall and rainfall with a short dry season. These



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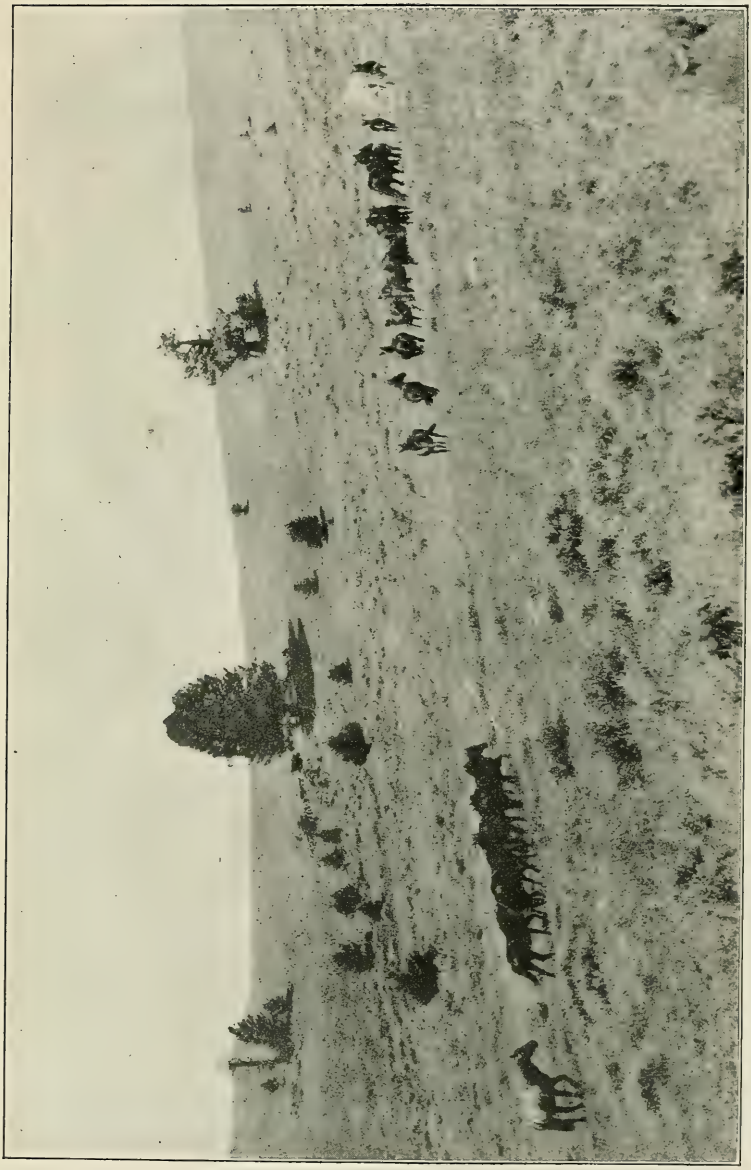
Cattle prefer open grass parks and meadows close to water and near shade.



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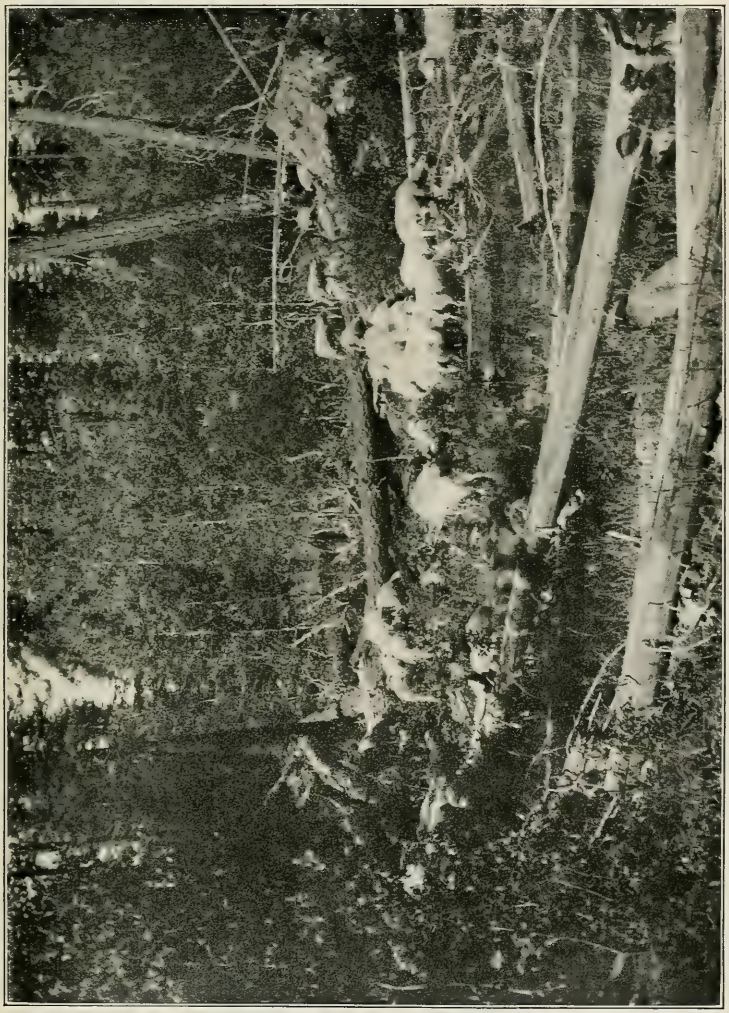
Horses prefer high open grass ridges when ranging in the mountains. As compared with cattle they will travel long distances to water. Horses often become very much attached to ranges on which they have run as colts, and will in many instances return after long periods of enforced absence.



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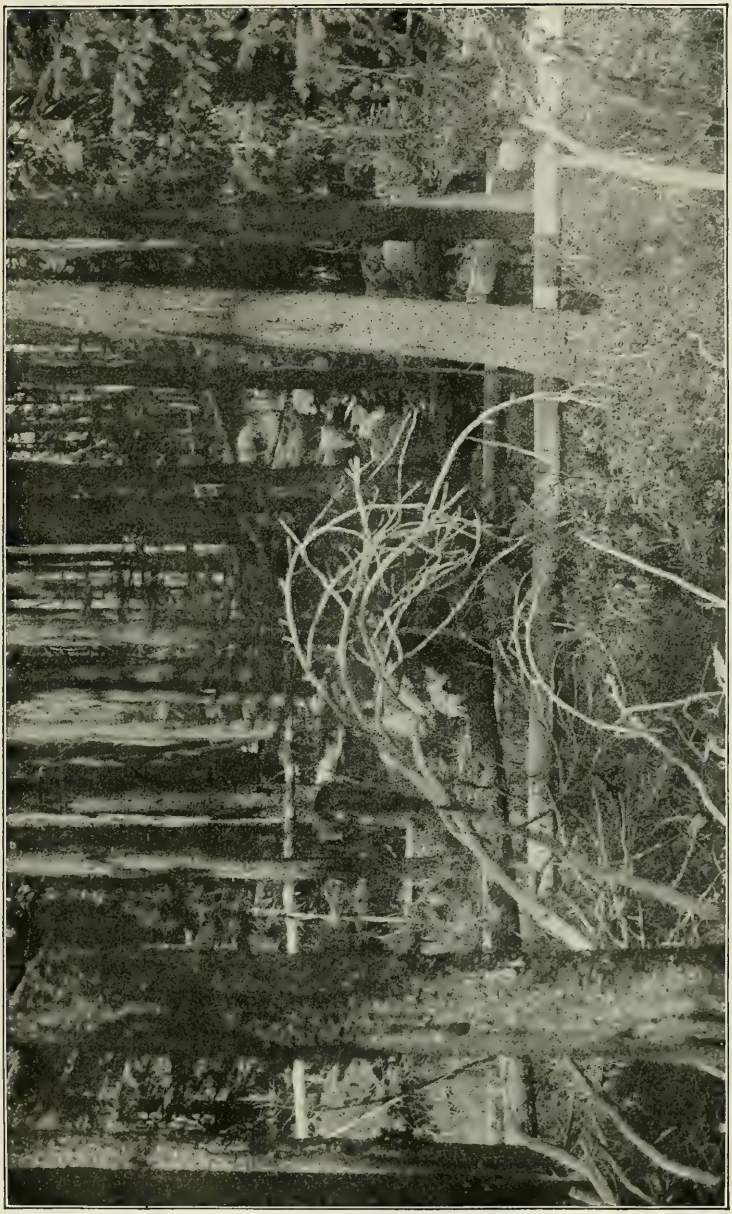
Sheep will penetrate and utilize small areas of fallen timber or brush. They can easily utilize areas that can be ridden through on horseback, and if quietly handled they will use areas which a horse can not get through.



Sheep unherded in a fenced area in Oregon. They made good use of large areas of range in dense timber. At night they left the heavy timber and bedded on the untimbered or openly timbered ridges.

conditions are favorable for the breeding of flies, gnats, and mosquitoes during the time the stock should be on the range. In some cases the ranges may be grazed after the fly season has passed. Ordinarily, however, this can not be done, as the grazing period in high altitudes is short at best, and the time left after the fly season is too short to warrant putting the cattle and horses on, or so short that full use of the range is not possible.

Sheep are annoyed by these insects, but much less than cattle or horses. Usually no consideration need be given to this factor in alloting sheep to a range within the National Forests, but in a few localities adjustment in the time of grazing may be necessary.

PROTECTION OF GAME.

The forage habits of elk and deer are similar to those of cattle and sheep. Both elk and deer, however, show a greater preference than cattle for weeds and browse.

Game animals in many instances voluntarily choose areas not well suited to the grazing of domestic animals. More often, however, this choice is forced by several influencing factors that might all be grouped under the one heading, "Man."

Mountain sheep and mountain goats are now very seldom found either in summer or winter on ranges accessible to any class of domestic stock. However, mountain sheep should be protected from disturbance and competition in the utilization of forage by domestic sheep in the few instances where domestic sheep otherwise would utilize rough range inhabited by mountain sheep.

Deer and elk in a majority of cases must be protected from domestic stock, particularly sheep, which are capable of utilizing almost any range on which game animals might seek seclusion. During the summer months elk, and in many instances deer, will be found at the higher elevations feeding mainly on the weeds growing in the alpine parks, either among the rocks or in the timber, where there is ample water and shade. In winter elk and deer come to the lower, open foothills, usually feeding on steep, open wind-swept exposures. If unmolested, elk will browse extensively in willow patches during the winter.

Moose are usually found in rolling timber country where bogs, ponds, and lakes are numerous. Such areas are seldom of very great value for the grazing of domestic stock. While timbered areas of this kind are usually poorly stocked with forage plants, they are also in most instances infested with flies and mosquitoes to a degree that would make the grazing of cattle and horses next to impossible except for a very short period of the year. It is usually a difficult matter, and in some instances impossible, to handle sheep economically in a country of the character suited to moose.

PROTECTION OF TIMBER GROWTH AND WATERSHEDS.

Experience and investigation have shown that, generally, grazing within certain limits, properly managed, does not interfere to an unwarranted degree with the protection, development, and conservative use of the forests and watersheds. They have made it equally evident, however, that grazing management must receive special consideration on certain forest lands and on certain watersheds. These important cases usually will be given special study and consideration after the general division of range between different classes of stock has been made. Specific suggestions for the handling of such cases are given under the heading, "Grazing and protection of timber."

In apportioning range among different classes of stock it is important to keep in mind:

1. That where the intensity of the grazing is the same sheep graze young growth of more timber species than do cattle, and that they cause greater injury to young growth, and, in general, to watersheds, though on steep slopes with loose soil cattle grazing may be more destructive to the watershed than sheep grazing.

2. That injury to tree growth by cattle and horses is negligible if overgrazing and bad management of stock are avoided.

3. That injury to tree growth by sheep depends greatly upon the character of the forage, increasing as the proportion of forage not suited to sheep increases, and that timber reproduction on dry grass ranges or other ranges where there is little succulent weed growth or browse suitable to sheep is especially subject to injury by sheep grazing if the forage is fully used.

4. That sheep in herds on steep slopes where the soil is loose may trample out tree seedlings to an appreciable extent.

Aside from these special points the main features of importance are to see that seasons of grazing are properly adjusted, overgrazing avoided, and the stock properly handled. These features need be considered in the division of range only to the extent of deciding whether the desired management of the range and stock in question is practicable.[1]

LAMBING RANGE.

For areas used by sheep during the lambing period at least two requirements are necessary: Ample green feed suited to sheep, so that the ewes will produce sufficient milk for the lambs, and an altitude low enough not to be subject to severe wet storms during the lambing period. Such storms occur occasionally on any lambing range, but at high altitudes they are frequent at lambing time and the weather generally is cold and wet. A good lambing range should have natural protection from storms. This is afforded by broken topography

[1] The selection of goat ranges is a special problem and does not enter as a major problem into division of ranges in general.

with small canyons, basins, and coves. Such broken topography is an advantage, too, in keeping ewes and young lambs in small bunches for the first 10 days after the lambs are dropped.

The general tendency has been to use for lambing grounds areas not suitable for this purpose, owing to altitude, lack of sufficient green feed, and poor protection. The use of such areas should be discouraged in favor of earlier lambing on feed if necessary. Sheep owners will undoubtedly aid in this, as the losses on unfavorable lambing range are unwarranted and the number of lambs saved is becoming more important as a factor in determining net profit of the sheep business.

RANGE DIVISION LINES.

Division lines between ranges used by different classes of stock are often established without enough attention to the suitability of all range within a unit to the class of stock assigned to it. The aims naturally are to establish the division lines along the most prominent ridges and streams and to satisfy demands of individuals and communities. This practice in general is correct. Very often, however, division lines based on prominent ridges and streams may be so general as to include within exclusive cattle range areas of considerable size which can be well utilized only by sheep. This is due to the fact that cattle utilize the lower slopes and more accessible places but make little use of the less accessible areas, usually at the upper parts of the watershed, which could be fully utilized by sheep without interfering with the cattle interests or damaging the watershed. Less often areas of considerable size best suited to cattle are included within exclusive sheep range. All the area within a proposed unit boundary should be carefully examined to determine the suitability of the range to the proposed class of stock. If satisfactory boundary lines can not be decided upon so as to exclude range not suited to the class of stock on the unit, common use with more than one class of stock should be considered. The minimum area which it will be practicable to exclude from the unit will have to be decided for the individual case.

COMMON USE OF RANGE BY DIFFERENT CLASSES OF STOCK.

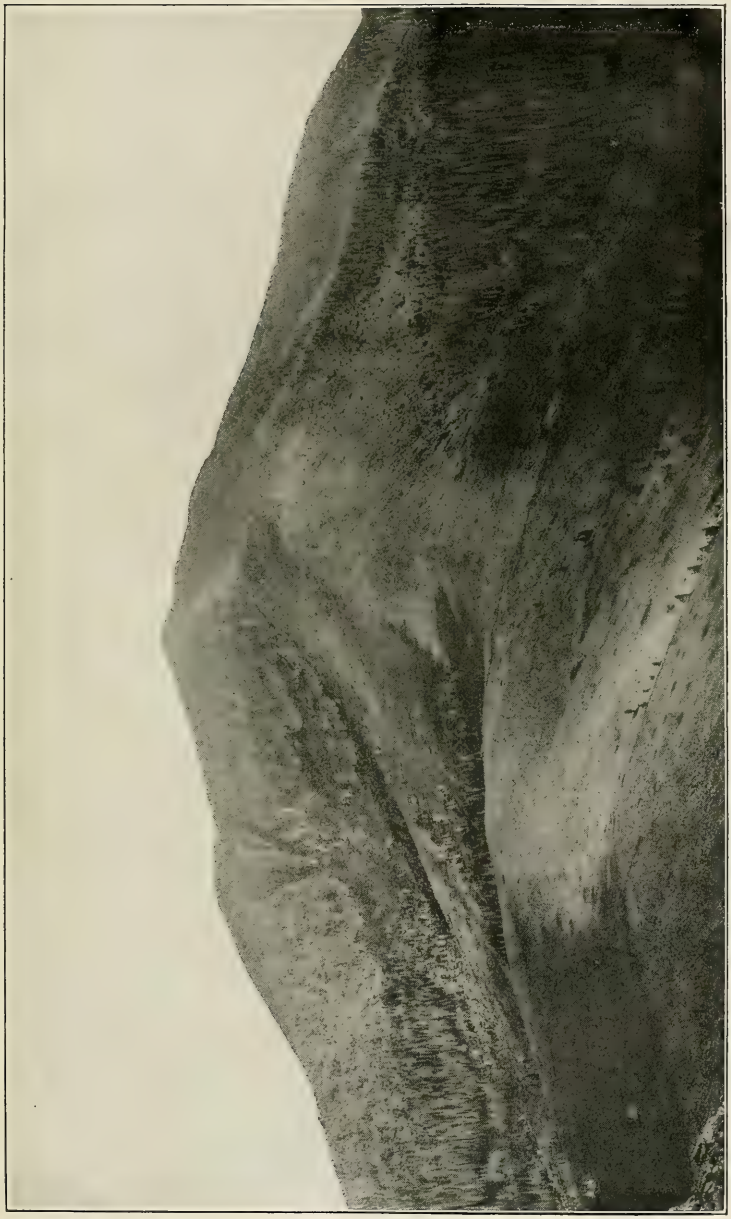
If a range unit can be fully and properly utilized by one class of stock, there is nothing to be gained by grazing two classes in common. It is becoming more and more evident, however, that on mountain lands, such as those within the National Forests, the range units wholly suited to exclusive use by one class of stock are small in number as compared with those which can be fully utilized only by two or more classes. Nature has not provided forage plants, topography, and watering places over arbitrary administrative divisions as large

as the average grazing unit to suit the requirements of exclusive grazing by one class of stock.

To obtain full utilization of the forage and maximum grazing capacity one, two, or more classes of stock may be grazed in numbers corresponding to the quantity of forage which can be used best by each class. Where the range supports a variety of plant species, including a good deal of grass forage, or where there is an appreciable area of meadow range, cattle grazing, if not overdone, is a benefit rather than a detriment to the sheep interests. In heavy feed cattle will trample down some of the weed feed suited to sheep, but the use of the coarse grasses by cattle will prevent the grasses from crowding out the weed forage, as they are doing on many ranges which have been grazed exclusively by sheep for a number of years. On the other hand, sheep grazing on a cattle range where there is a good deal of weed feed, or on small areas difficult for cattle to reach, not only is economy, but aids in maintaining the cattle feed by keeping down the weeds. A few horses may in some cases be grazed to advantage on sheep range, cattle range, or range used by both sheep and cattle. The horses will use to advantage grass range not well suited to sheep and too far from water or too rough for full use by cattle. And it is not improbable that in localities where goats are produced a few goats may be grazed to advantage on cattle or sheep ranges to keep brush stands open enough for the growth of vegetation suitable for the other classes of stock.

The main reasons then for common use of range are to prevent waste of forage and to maintain a normal balance between the different kinds. Success in common use depends upon establishing the right proportion between the different classes of stock to correspond with the proportion of the forage which should be used by each class. This must be done to avoid overgrazing of the range as a whole and to avoid unwarranted encroachment of one class of stock upon another.

There usually is sufficient forage suited to both sheep and cattle to admit of considerable variation in the ratio between the two. Where the forage is 50 per cent weeds and 50 per cent grasses sheep and cattle might be run in ratios of 3 to 1 to 6 to 1, depending upon the amount of range the cattle will not use because of ruggedness or distance from water and upon the character of the grass and weed forage. At best, then, careful study of the range is essential to the establishment of the proper ratio, and very often the desired balance between sheep and cattle can be worked out only by observing the utilization of the range and readjusting the numbers of stock from season to season until the forage crop is utilized as it should be. If a considerable quantity of grass feed is left at the close of the grazing season, it would seem reasonable to consider



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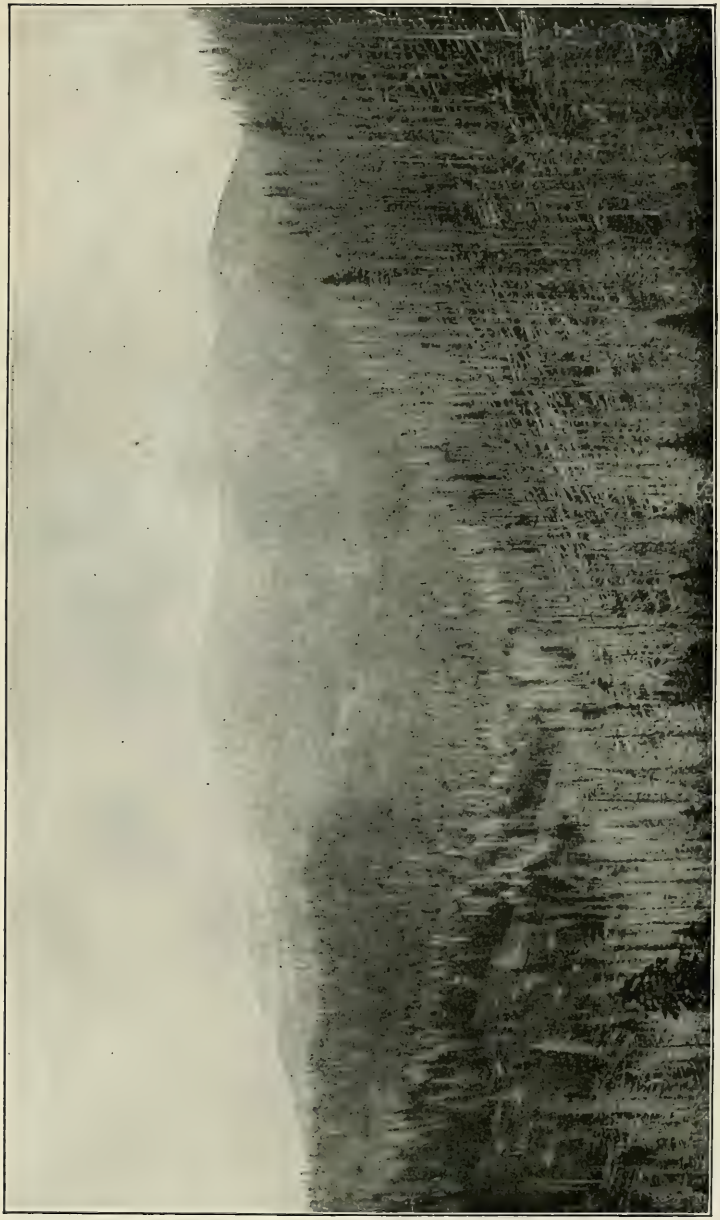
The accessible spots on high and comparatively rough ranges such as this can be utilized to best advantage by sheep.



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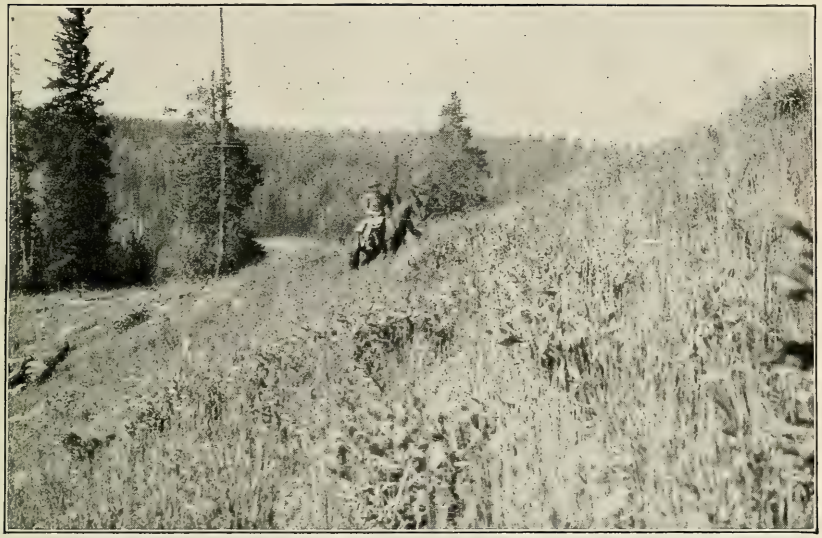
There are many waste areas on our Forest ranges. The slope represented in the right foreground is typical of the most common inaccessible range type. The areas to the left and in the background are good sheep range.

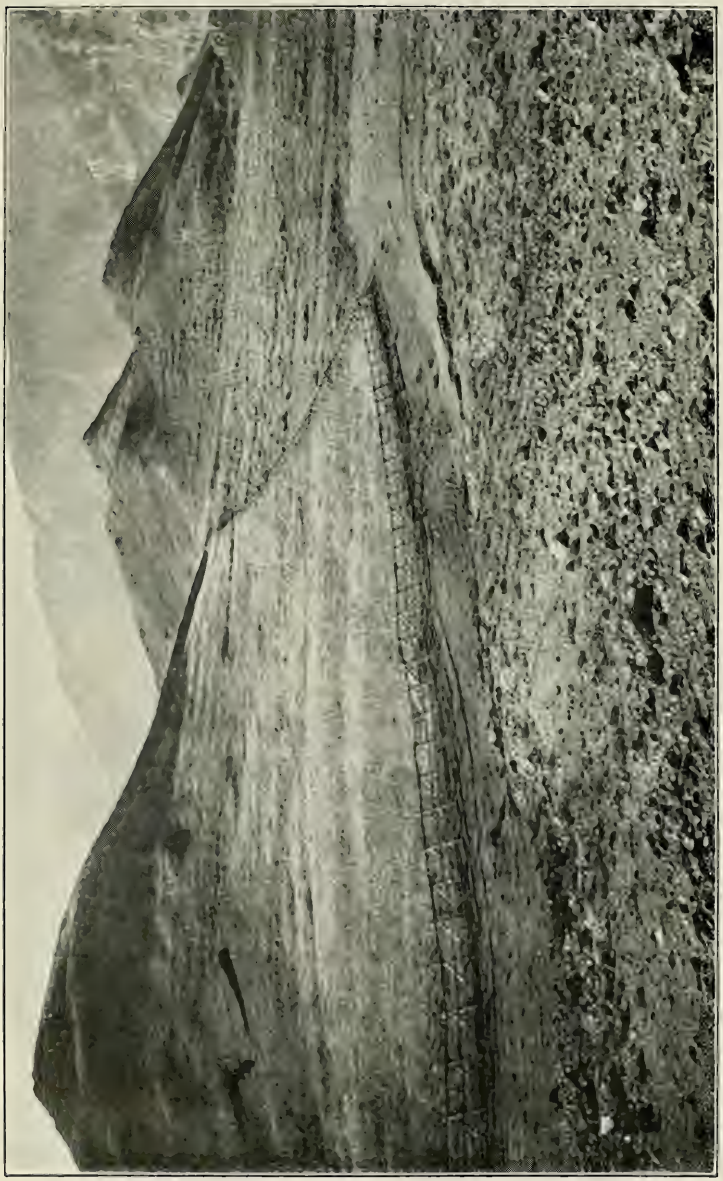


F-2-WRC

Fig. 1.—A combination of grass and weed type which should be grazed by both sheep and cattle if the fullest possible use is to be made of the range. Sheep will take very little of the coarse grass feed unless compelled by a shortage of weed feed. Cattle will eat but very little of the weed feed if there is sufficient grass.

F-3-WRC

Fig. 2.—An area of coarse grasses on a sheep allotment that can not be utilized properly by sheep. Cattle make the fullest use of such areas.



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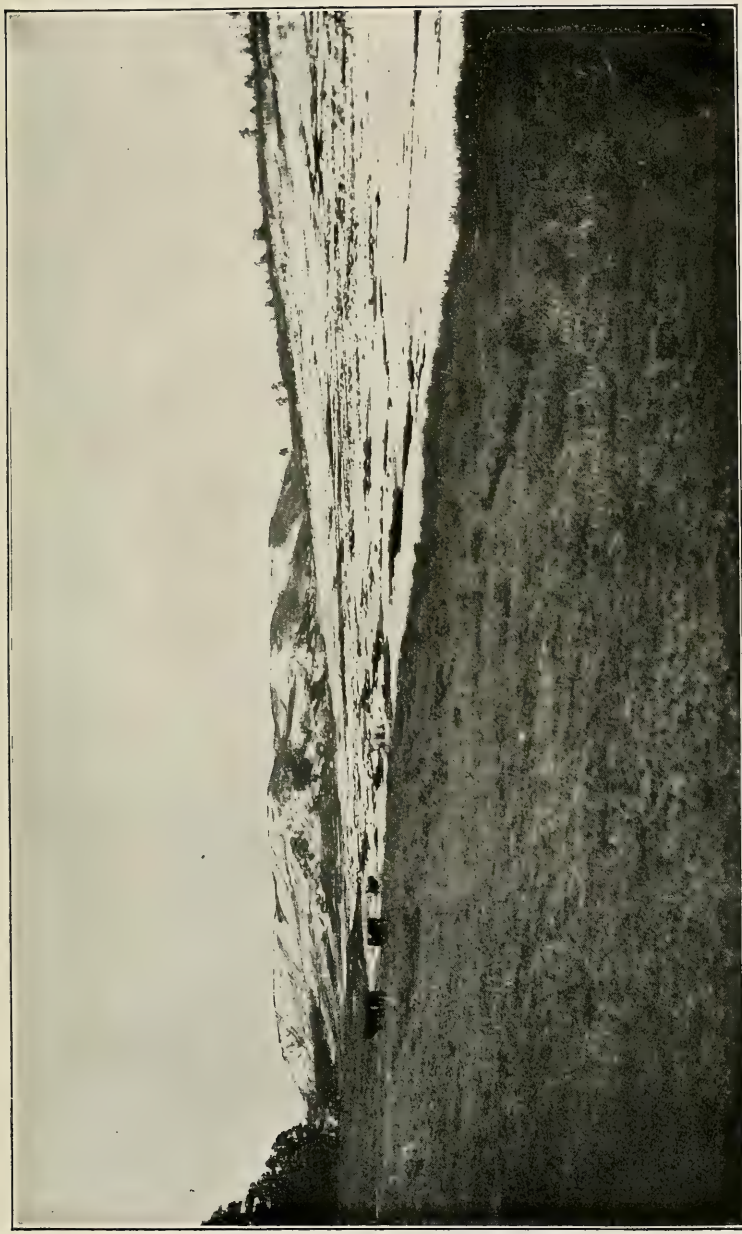
Premature grazing on the right of this fence has resulted in a great reduction in grazing capacity. This happens where cattle are turned on the range at the first signs of plant growth in the spring.



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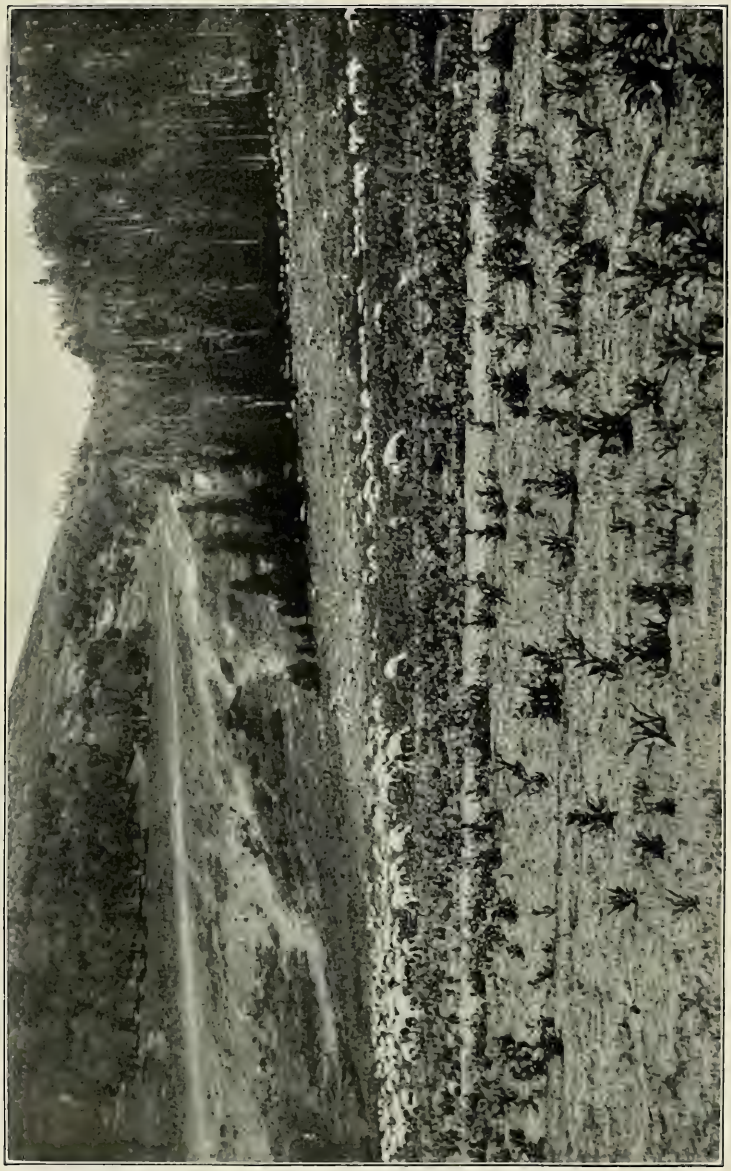
Cattle, if permitted to do so, will often follow the receding snow and injure the range through too early use.



A sneezeweed type on an overgrazed sheep range.

increasing the number of cattle. If weed feed is left, an increase in sheep might be desirable.

The old-time belief that cattle will not graze on a range used by sheep is erroneous. It originated mainly when the ranges were badly overgrazed. There was little or no feed of any kind left for cattle after sheep grazing. Naturally cattle would not stay on such range. Overgrazing and an excessive number of either class of stock must be avoided, and the stock must be properly handled. These, however, are difficulties which have been repeatedly overcome in practice and undoubtedly can be overcome in the majority of cases.

In practice on ranges on the National Forests cattle and sheep are sometimes found grazing together, but usually the two classes of stock graze over the range at different times or graze different portions of the range. The parts best suited to cattle and most used by this class of stock are lightly grazed by sheep at a time when there is least interference with cattle. The areas not suited to cattle or not used by cattle furnish the main grazing for sheep.

Where the use of the range is regulated there is little need for conflict other than in opinion, and this should not stand in the way of conservative use of the grazing resources. A great many summer ranges should be grazed by both cattle and sheep. Either class can not wholly replace the other. It seems logical, therefore, to expect that common use will be given careful study and, where conditions warrant, will be made a requirement if such action becomes necessary to secure full use and protection of the range resources.

IMPORTANCE OF GRAZING THE CLASS OR CLASSES OF STOCK TO WHICH THE RANGE IS SUITED.

The importance of careful study to determine the class or classes of stock to which a range is best suited can not be overemphasized. The many reasons can not be given here without including in this place much discussion which more properly belongs under the headings which follow. The reader is urged, therefore, to note carefully the importance of suitability of range to the stock in determining season of grazing, grazing capacity, management of stock, losses from poisonous plants, and damage to tree growth by grazing. The problem of division often is difficult, because it involves not only the suitability of the forage, but also the comparative difficulties of handling the different classes of stock so as to utilize the forage without unwarranted damage to other resources. The fact that large range units have been classed as cattle range or as sheep range for years does not necessarily mean that the original classification is infallible. A unit as a whole may be best suited to the class of stock already on it and yet afford much opportunity for interior classification which will result in segregation of range for another class of stock or for common use.

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GRAZING PERIODS.

PREMATURE GRAZING.

In establishing grazing periods the first care should be to prevent damage to the range through premature use. In doing this there can be none but fancied wrong done the live-stock interests. The permanent welfare of the live-stock business itself demands that the grazing seasons should not begin too early, because the maintenance of the maximum permanent carrying capacity of the range is identical with the permanent welfare of the communities or individuals depending upon the range.

Premature grazing was undoubtedly one of the foremost causes of the deterioration of range lands prior to regulated grazing; and the fixing of grazing periods on the lands within the National Forests has had as much to do with range improvement as reductions in number of stock, if not more. There is much to be done in adjusting the grazing periods so as to fit the requirements of all range covered by each period.

The growing herbage might be called a laboratory where plant nutrients are prepared. Repeated removal of this herbage year after year during the early part of the growing season destroys this laboratory, and by doing so robs the vegetation of nourishment. As a result the vitality of the forage plants is lowered, the forage production is reduced, and the weakened plants are unable to produce fertile seed.

Meanwhile the plants little grazed by stock, or not eaten at all, will be growing vigorously and will eventually occupy the range.

The damage to the forage plants from premature grazing is greatest immediately after growth begins and decreases as the growing season advances. Little or no damage is done after the plants have matured seed. In a broad sense, therefore, grazing at any time before seed maturity of the forage plants may be considered premature. It is not practicable, however, to allow all of the range to go ungrazed until after seed maturity in any one year. The problem is to work out seasonal grazing which will result in maximum production of forage and live stock year after year. Such a plan involves: (1) Fixing the opening of the grazing period so that the damage from grazing will not be irreparable or out of all proportion to the value of the forage secured and (2) adjusting grazing after the season opens so that all portions of the range will be grazed as nearly as possible in harmony with the requirements of the vegetation making up the forage crop.

WHEN THE GRAZING PERIOD SHOULD OPEN.

The importance of avoiding too early grazing can not be overemphasized. It will be to the ultimate advantage of the range users to feed their stock or otherwise provide for them until the range may properly be opened to grazing. It is especially important to avoid—

1. Cropping of the herbage as soon as the earliest plants afford a small supply of forage.

2. Admitting stock before at least 25 per cent of the heads of the earlier forage grasses have begun to show or before the leaf sheath involving the head is swollen and conspicuous.

3. The presence of stock while the soil is saturated or while there is moisture enough so that the trampling by the stock will result in appreciable packing and hardening of the soil when it dries.

If grazing starts when the earliest plants afford a small quantity of forage the leafage is extremely succulent, low in nourishment, and insufficient in amount properly to maintain the animals. In an attempt to get enough nourishment they cover a large area and, by trampling, do unwarranted damage to young plant growth and soil. The removal of the herbage at this stage of growth is extremely detrimental to the later growth of the plants, greatly reduces the total food production, retards the production of flower stalks and the time of seed maturity, decreases the quantity of seed, and lowers the viability of what seed is produced. In addition, cases have been known where heavy unnecessary losses have occurred when cattle already in poor condition were turned on range prematurely and died because there was insufficient nourishment in the soft, washy

young grass to maintain them through the necessary period of recuperation.

By the time 25 per cent or more of the heads of the earlier forage grasses begin to show or are conspicuous in the sheath sufficient leafage has been produced to afford a good bit of forage. It is then unnecessary for the animals to travel great distances for the supply of food needed, and the damage from grazing is not nearly so great as during the earlier period. This stage of development comes normally from 10 days to two weeks after growth begins.

Grazing when the soil is saturated or very wet results in packing the soil by trampling, so that it hardens when it dries. In this condition it does not absorb later rainfall as readily as when mellow, as it ordinarily is if not trampled. As a consequence, the moisture available for the plants is reduced and erosion is more active than on unpacked soil. The greatest danger from trampling and packing is over, normally, so far as the spring period is involved, by the time the main forage plants have been growing about two weeks.

Two weeks, then, after growth of the earlier forage grasses begins may be set as the earliest date at which stock should be allowed on the range. Where overgrazing or premature grazing has been practiced until the range has deteriorated the opening of the season may have to be delayed longer, or it may be necessary to apply deferred grazing on the overgrazed area to allow the range to recuperate.

The beginning of growth for a given exposure is later by about 7 to 10 days for each 1,000-foot increase in altitude, and there is considerable variation in the time at which growth begins on different exposures of the same altitude. Further, the time at which growth begins varies somewhat in different years, perhaps as much as two weeks. On the other hand, the opening date of the grazing period for any one year must be decided in advance, but may be changed in years following. These various factors must be kept in mind and harmonized as far as practicable in deciding this opening date. In doing so the following suggestions may be helpful:

1. On spring ranges and on summer ranges decide upon the area which should be used during approximately the first third of the period.

2. Allow grazing to begin when the early forage grasses at about the center of altitude on this area are in the head.

3. Inspect this range for a number of years to determine the average date at which the early forage grasses at this central altitude are in the head, and eventually use this date as the beginning of the grazing period.

The choice of one-third of the range and of the central altitude of this third may not fit an individual case; but it will serve as a

suggestion of a method of procedure in deciding this vital and complex question.

On fall and winter ranges the main point is not to begin grazing so long as the stock can be taken care of properly on the summer range. Winter is a critical period and the forage crop the following spring is uncertain. Consequently reservation of feed for winter is always an advantage.

SEASONAL GRAZING AFTER THE PERIOD OF GRAZING BEGINS.

Established grazing periods sometimes cover spring, summer, and autumn range varying perhaps as much as 5,000 feet in altitude. Throughout this variation in altitude a given stage of growth of the vegetation is delayed about 7 to 10 days for 1,000 feet of increase in elevation, making a total of 35 to 50 days' difference between the lower and the upper limits.

Where such range is used by sheep under herding, a definite plan can be followed to adjust the time of grazing at a given altitude so as to correspond approximately with the development of the vegetation. Such a plan should be worked out and followed. The control of cattle, however, is usually inadequate to accomplish this desired seasonal grazing. As a consequence the cattle drift to higher altitudes before the vegetation should be grazed. Where this is the case the object of establishing a grazing period is accomplished only on the extreme lower altitude. The rest of the range is injured by too early grazing. Sometimes this injury is out of all proportion to the value of the forage secured. Open basins and ridges at the heads of drainage may soon become impaired to such an extent as to necessitate reduction in the number of stock or, in some cases, exclusion of stock while the range is being built up. The remedy is to work for a logical division into spring range, extending to about July 1, and summer range, beginning about July 1, with corresponding control of the cattle and horses. It is impossible to do this at once in all cases where it should be done; but observations, adjustments, and plans should be made with this division or a similar one to fit the individual case in view.

Even within these suggested divisions repeated close cropping of the vegetation after the first two weeks of growth will result in deterioration of the range. Care should be exercised to see that grazing is uniform and not heavy during the early part of the grazing period; and if the range is to be grazed to full capacity a system of deferred and rotation grazing, as described under "Range Reseeding," should be applied.

The idea is sometimes advanced that too early grazing by cattle will not do as much damage to a range as too early grazing by

sheep. This belief is due to the closer cropping by sheep and to the fact that sheep are handled in bands and may pack the soil more than cattle. Too early grazing of the same intensity by either class of stock, however, will produce essentially the same result. When the soil is wet cattle do as much damage as sheep or more. They sink deeper into the soft ground, slide around more, and tear or press out more vegetation than do sheep under similar conditions and equally heavy grazing.

THE CLOSE OF THE GRAZING PERIOD.

The close of a late spring grazing period should be governed by the time that grazing on the summer range may properly begin. If the spring range will not carry the stock on it until this date, there are too many stock. The close of a summer grazing period should be governed, as a general rule, by weather conditions and by the supply of fall and winter grazing. Late grazing, when not accompanied by bad management of the stock, will not injure the stock. However, it is not advisable as a general policy to graze the range in the fall as long as the stock can get enough forage to live on. A little old feed in the spring and early summer may be necessary to help carry them in case of a late growing season and a consequent shortage of new forage growth. Whether the old forage to be reserved for use the following year is provided by an earlier close of the grazing season than would be necessary if no feed is reserved, or by reducing the number of stock without a change in the season, depends upon local conditions.

The close of winter and early spring grazing periods should be governed by the main growing period of the vegetation on the range in question. If the range is to be kept up and a normal forage crop produced over a period of years following, the vegetation must be given a chance to grow. This means that stock should be removed at the beginning of the main growing season.

Where yearlong grazing is practiced on range of comparatively uniform altitude, the number of stock should be reduced about 50 per cent during the main growing season of the main forage species on the area, and the stock left on the range should be kept well distributed. Further study may show that a reduction greater or less than 50 per cent will give the best results in total animal feed furnished each year over a period of years. It may also show that, in addition to reduction of stock, a system of deferred and rotation grazing may be necessary in order to secure the maximum animal feed over a period of years. In the absence of reduction of stock during the main growing season, a system of deferred and rotation grazing to give the forage on each portion of the range a chance to grow to seed maturity occasionally is imperative.

SHORTER GRAZING PERIOD AND MORE STOCK.

The question frequently comes up of shortening an established grazing period and proportionately increasing the number of stock. If the established season is such that the best and fullest use is being made of the range in question, any considerable shortening of the grazing period will result in waste of forage or overgrazing of the forage plants preferred by the class of stock grazed. If the established grazing period is not such as to result in the best and fullest use of the range, the period should be changed and the grazing capacity redetermined after careful inspection. It must be borne in mind that plants have their periods of highest palatability and that this varies for different important forage plants on the same area. Shortening the grazing period, for example, on central Utah range by an earlier close would result in great loss of elder[1] feed, which is seldom eaten by sheep in this locality before the first heavy frost. A number of browse species ordinarily are only lightly browsed before the latter part of the season. To shorten a properly adjusted grazing period by setting a later date of opening would likewise result in waste of forage from many rapid-growing plants drying up or reaching a stage of low palatability before grazing begins. The result in either case would be a decrease in the total feed furnished; consequently, an increase in stock proportionate to the reduction in grazing period could not be made without danger of overgrazing. These suggestions apply, of course, to range in normal condition. Ranges partly or wholly depleted of the most desirable forage plants may require a later date for opening the grazing season than the date for the same range in normal condition. The sacrifice of forage from rapid-growing plants is warranted if it will result in improvement of the range by increasing the more desirable forage plants.

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GRAZING CAPACITY.

Grazing capacity, as used here, means the number of stock of a given class or classes which a range unit will support for the period of grazing allowed. The ideal sought is the maximum number of stock which the unit will support each season over a period of years without injury to the range, tree growth, or watershed, or unwarranted interference with game and recreation. If this ideal is to be realized, both overgrazing and unnecessary undergrazing must be avoided.

OVERGRAZING.

Overgrazing may be defined as grazing which when continued one or more years, reduces the forage crop or results in an undesirable change in the kind of forage. Such grazing may exist over an entire forest, but this is not likely with regulated range use. It may exist over an entire large unit of cattle range or sheep range, but seldom does. It occasionally exists over small cattle units or individual sheep allotments, as a whole. Most often, however, overgrazing occurs locally on parts of cattle range or sheep range because of poor distribution of the stock or improper handling, or both.

It is apparent, therefore, that an overgrazed spot on an allotment does not mean that the allotment, as a whole, is overgrazed. Nor does overgrazing on a few allotments mean that the forest as a whole is overgrazed. On the other hand, the fact that the forest, as a whole, or a range allotment, as a whole, is not overgrazed does not mean that portions of either or both are not, even seriously, overgrazed. Usually the difficulty can be remedied by more uniform distribution of range by units, better distribution of stock on each unit, and better handling of the stock. To get results, however, the man on the ground must be able to recognize both overgrazing and undergrazing and the causes and remedies for each.

In determining whether a range is overstocked for any current year to a point where overgrazing will result, both the condition of the range and the condition of the stock at the close of the grazing season must be carefully observed; also the period during which the range is grazed is important. If a range, for example, is not grazed or is only lightly grazed during the main growing season of the principal forage plants, but is heavily grazed later in the season, the forage suitable for stock may be entirely consumed without damage to the range. The same intensity of grazing during the growing

season would result in injury to the range. On most ranges, however, there is at least a small supply of forage made up of plants of which stock will eat very little except in case of necessity. It is best to graze the range so that stock will not be forced to eat this forage of low palatability. Close grazing of this class of vegetation therefore is an indication that the range is overgrazed, provided the range is suited to the class of stock on it. (*See* Class Overgrazing.) Under such conditions the condition of the stock will not be satisfactory if grazing has been reasonably well distributed over the grazing unit. On the other hand, stock may be thin at the close of the grazing season without the range being overgrazed if a large part of the forage is unsuited to them.

Perhaps the most common mistake is to assume that because the stock are in satisfactory condition at the close of the season there is no overgrazing. This may or may not be true. Not infrequently stock in good condition at the close of the season are from ranges on which there is severe overgrazing. Where this is the case there is faulty distribution of grazing, which may be remedied by water development, proper salting, riding, fencing, or a change in the class of stock. Also, stock may be taken off in good condition from a range which has been injured by too heavy grazing during the growing period of the main forage plants.

The point of importance in this connection is that the condition of the stock when taken off the range is not in itself a reliable indication that the range is not overgrazed. It is true also that no one of the other indicators of overgrazing should be taken as conclusive evidence that a range is being overgrazed or has been overgrazed in the past. Careful examination and observation will usually reveal more than one of these indications of overgrazing.

INDICATORS OF OVERGRAZING.

Overgrazing for an extended period will leave "earmarks," which usually will be recognized. To recognize current overgrazing at the time of examination on a range previously not overgrazed is difficult and yet important in order to make timely adjustment. The following more obvious earmarks are the most reliable indicators of overgrazing prior to the year of examination:

The predominance of annual weeds and grasses, such as knotweed,[1] tarweed,[2] mustard,[3] annual brome grasses,[4] and fescues,[5] with a dense

[1] Knotweed, *Polygonum* spp.

[2] Tarweed, *Madia* spp.

[3] Mustard, *Sophia incisa*.

[4] Annual brome grasses, *Bromus hordeaceus, B. brizaeformis, B. tectorum,* and others.

[5] Annual fescues, *Festuca megalura, F. microstachys, F. bromoides, F. confusa,* and perhaps others.

stand of such species and lack of variety in species. This condition is a severe stage of overgrazing such as occurs around sheep bedding grounds which have been used for long periods each year for several years in succession.

The predominance of plants which have little or no value for any class of stock, such as sneezeweed,[1] niggerhead,[2] yellowweed,[3] snakeweed,[4] and gum weed.[5] These and similar plants frequently occur in abundance over large areas of range and indicate that the range needs careful management to give better forage plants a chance to grow.

The presence of dead and partly dead stumps of shrubs, such as snowberry,[6] currant,[7] willow,[8] service berry,[9] birch-leaf mahogany,[10] and Gambel oak.[11] This condition usually indicates that the most palatable grasses and weeds have been overgrazed. There may be some exceptions to this, as in the case of dwarfed willows on ranges where grasses predominate above timber line. Sheep sometimes kill the willows before the grasses are overgrazed.

Noticeable damage to tree reproduction, especially to western yellow-pine[12] reproduction on sheep range and aspen[13] reproduction on cattle range. Lack of aspen reproduction on a weed sheep range indicates overgrazing, provided the natural conditions are favorable to aspen reproduction. On a sheep range where grass predominates severe injury to western yellow-pine or aspen reproduction may indicate that the range is not well suited to sheep.

Erosion and barrenness, accompanied by a network of stock trails, where formerly there was a cover of vegetation. These are typical of areas where overgrazing has reached the extreme stage.

The earmarks described are, perhaps, more typical of overgrazed sheep range than of overgrazed cattle range, but the general appearance of the two does not differ greatly when overgrazing reaches a stage to be recognized by one or more of these earmarks. The main differences are in the species of plants indicating the overgrazing. Weeds eaten by sheep are often found in abundance on overgrazed cattle range; coarse grasses palatable to cattle are often abundant on overgrazed sheep range. This fact has given rise to the use of the term "class overgrazing."

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[1] Sneezeweed, *Dugaldia hoopesii.*
[2] Niggerhead, *Rudbeckia occidentalis.*
[3] Yellowweed, *Senecio eremophilus.*
[4] Snakeweed, *Gutierrezia sarothrae.*
[5] Gum weed, *Grindelia squarrosa.*
[6] Snowberry, *Symphoricarpos oreophilus.*
[7] Currant, *Ribes* spp.
[8] Willow, *Salix* spp.
[9] Service berry, *Amelanchier* spp.
[10] Birch-leaf mahogany, *Cercocarpus montanus.*
[11] Gambel oak, *Quercus gambelii.*
[12] Western yellow pine, *Pinus ponderosa.*
[13] Aspen, *Populus tremuloides.*

CLASS OVERGRAZING.

The term "class overgrazing" originated in an attempt to designate a condition where the character of forage has changed materially as a result of continued grazing by one class of stock year after year. Where this condition occurs on a cattle range the plants most relished by cattle, usually grasses, decrease in abundance, and the weeds, less palatable to cattle but choice sheep feed, increase. Just the opposite change may take place on sheep range, the choice weeds decreasing and the grasses increasing. In either case, a good ground cover of plants suited to one or the other class of stock may be present after the range has deteriorated and has been reduced in grazing capacity for the class of stock allotted to it. This change appears to be a natural result where the range is grazed before the forage plants mature, because the development of the plants preferred by the given class of stock is lessened by grazing and the removal of these plants gives the less choice forage plants advantage in the natural competition.

Whether the change is due entirely to grazing or in part to natural factors, the result is not serious if the change is recognized and adjustments made so as to maintain the desired balance in forage plants—which means maintenance of an effective cover as well as of grazing value. This balance can be maintained with the least loss of forage by common use by the two classes of stock, as indicated under the heading "Determination of Class of Stock to Which Range is Best Suited." Where common use is not feasible a change in class of stock is needed, or deferred grazing should be applied, or, as a final resort, the number of stock should be reduced.

OVERGRAZING OF SCATTERING SPECIES.

The recognition and adjustment of class overgrazing involves the decision as to whether a range should be managed so as to perpetuate a species which is a very desirable forage plant, but which occurs only in scattering stands. This decision must be based upon the abundance and palatability of the species in question as compared to the abundance and palatability of the other plants which make up the forage crop. Good judgment in sizing up the local situation rather than any percentage figures on abundance and palatability is the essential factor in arriving at a conclusion. It is believed that no attempt should be made to graze so lightly that palatable forage plants which occur in scattering stands will be perpetuated in their original abundance. To perpetuate 10 per cent and waste 70 per cent of the available feed would be poor economy. On the other hand, it would be more disastrous to overgraze and eventually destroy 50 per cent of the forage in order fully to utilize 20 per cent which is low in

palatability. This is apt to occur on intensely used ranges. No rule of thumb can be laid down for guidance until all forest officers are familiar with the forage plants and their comparative palatability. The best that can be done is to recognize that an important problem exists and to look out for it and study systematically the life history and relative economic importance of the different range plants.

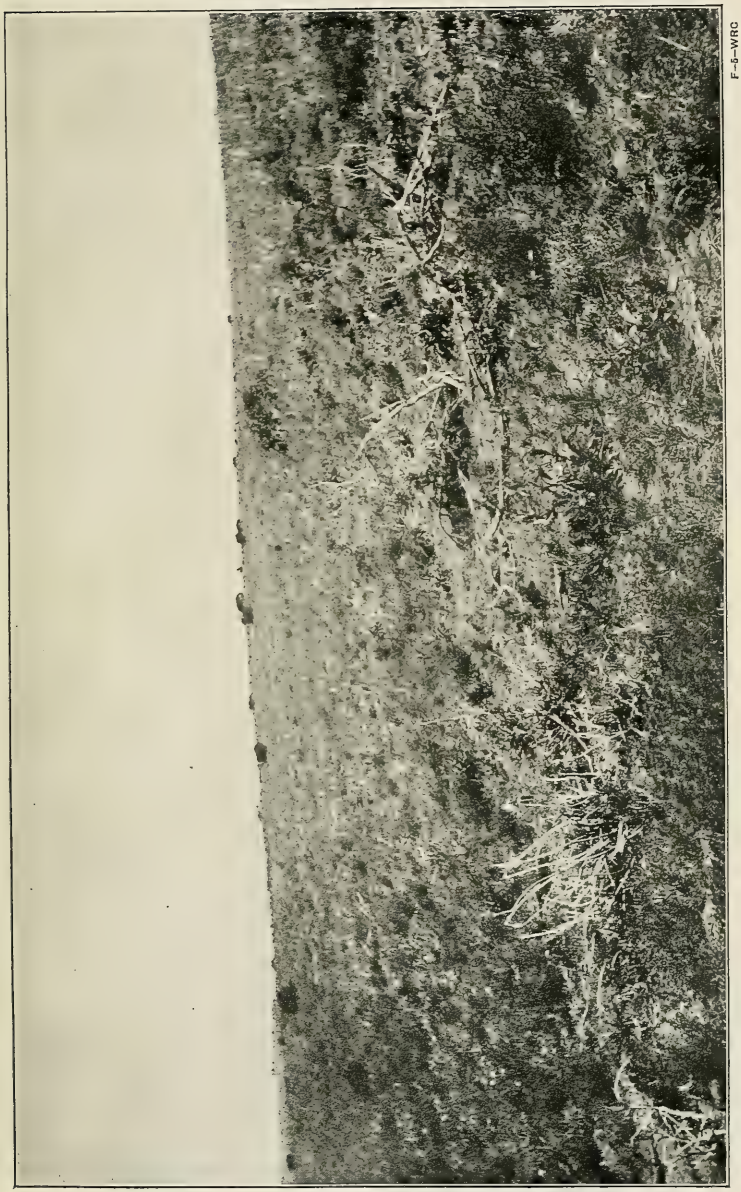
OVERGRAZING THE UNDERGROWTH ON BROWSE RANGES.

The forage crop on many browse ranges combines grasses and weeds with browse plants, the grasses and weeds growing on open spots or under the browse species. Grazing the browse as heavily as it will stand often results in overgrazing of the grasses and weeds. It is difficult to decide where to draw the line so as to maintain the most satisfactory combination. Data suitable for the basis of a definite rule are lacking and would be difficult to obtain, owing to the many variations in the combination of browse and herbaceous forage. It is hoped that intensive studies of browse range can be undertaken in the near future. A few suggestions, however, may be advanced at the present time.

Many species of browse are grazed by both cattle and sheep early in the spring when they first leaf out and again in late fall and winter, rather than during late spring and summer. This is partly explained, perhaps, by the greater abundance and succulence of grasses and weeds during the late spring and summer than in early spring, fall, and winter. In some cases this fact can be taken advantage of to increase the grasses and weeds by deferring grazing on the area until after the grasses and weeds have matured seed. The browse forage can then be utilized.

Where the palatable grasses and weeds make up approximately 25 per cent or less of the forage and are distributed throughout the browse they should be sacrificed so long as the grazing does not result in erosion, but care should be taken to watch this point, as it may occur while there is still unused browse feed. Where this 25 per cent of grasses and weeds is concentrated in small parks rather than distributed throughout the browse, lighter grazing of the area as a whole will be necessary, or denudation and erosion may result on the open lands and extend into the brush. Where the grasses and weeds make up approximately 50 per cent of the forage, grazing should be managed so as to perpetuate the herbaceous forage. In either case there will probably be unused browse feed except where the browse is made up of choice forage species. The surplus feed, however, will be an advantage as reserve feed for occasional years when conditions are unfavorable to forage growth.

The foregoing paragraph applies to the browse types usually at low altitudes in the woodland or below. On browse types following



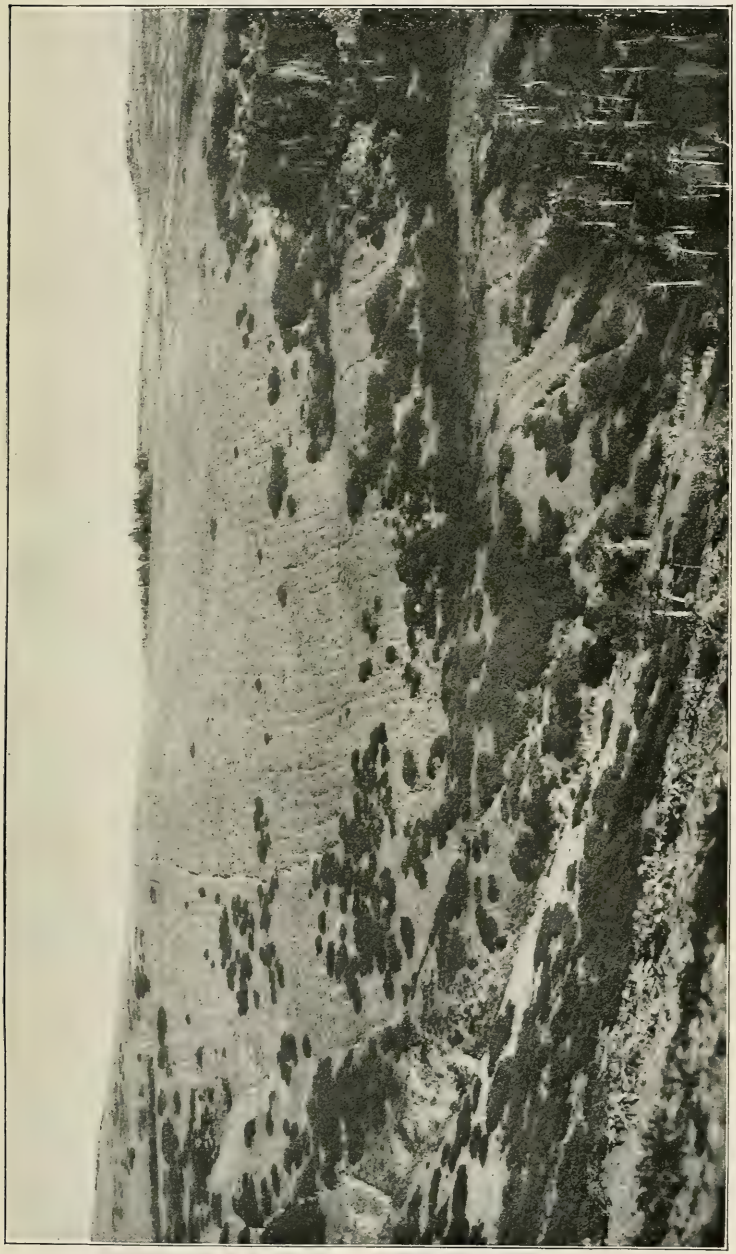
Palatable shrubs destroyed through overgrazing by sheep. Dead stumps indicate that this area once supported a good stand of snowberry.

F-6-WRC

Fig. 1.—Lack of aspen reproduction and absence of leaves as high as cattle can reach on overgrazed cattle range.

F-7-WRC

Fig. 2.—Dead and partly dead willows on cattle range. A good indicator of overgrazing.



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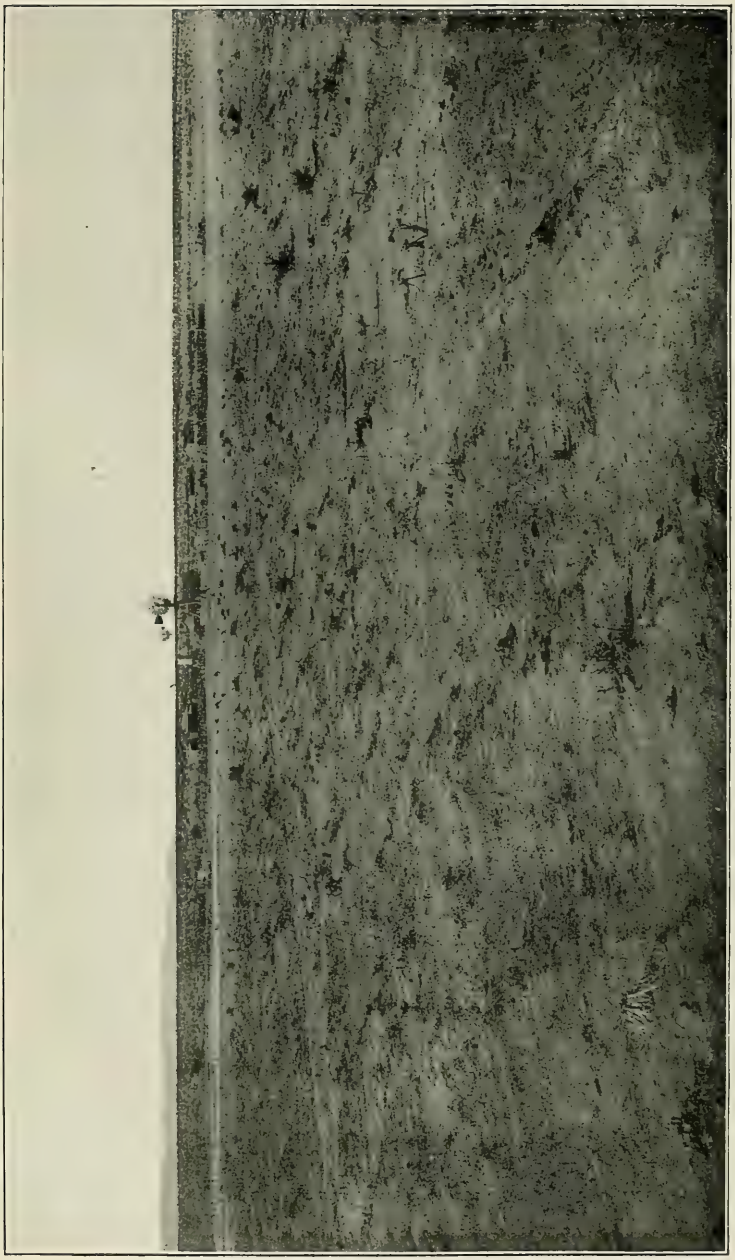
"Gulley" and "sheet" erosion on an overgrazed range.



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Denudation and wind erosion following premature grazing and overgrazing.

burns in conifer timber the object should be to restore the timber species, and grazing should be adjusted accordingly.

MAIN CAUSES OF OVERGRAZING.

If it is decided that an area is being overgrazed, the next step is to determine the cause, as a basis for remedial measures. The principal direct causes of overgrazing on National Forest ranges at the present time are too early grazing, poor distribution of stock, too many stock, and improper handling of stock.

Too early grazing by cattle is perhaps the most far-reaching cause of overgrazing on National Forest ranges at the present time. The practice too frequently has been to turn cattle loose on the low range adjoining the Forest lands or within the Forest and allow them to drift to higher altitudes as the snow line recedes and forage growth comes on. This practice has resulted in the grazing of range before the main forage plants have had two weeks of growth, which is believed to be the minimum period proper to allow between the beginning of growth and the beginning of grazing.

Usually the remedy is apparent but difficult of application. First, the beginning of the grazing period should be established in accordance with the suggestions on page 11, on Grazing Periods; second, there must be control at the Forest boundary to prevent the stock from drifting on the range before the date decided upon for the opening of the grazing period; and, third, there must be some form of control to prevent stock from leaving the low range too early and following the snow line to higher altitudes. Fences eventually, no doubt, will be constructed to control the stock. Meantime control by salting and riding should be exerted to the maximum extent practicable.

Too early grazing is not so common with sheep as with cattle. Lambing ranges, early spring ranges, and, occasionally, portions of high summer range, however, are grazed before the main forage plants have had two weeks of growth. The remedy again is obvious, though difficult to apply until lambing facilities are better adjusted to the changed condition of limited lambing range. The fact to recognize and face is that the small acreage of lambing and early spring range can not be stretched to meet increasing demands. It has its limit beyond which it is bad policy for the man permanently in the sheep industry to go, even if he is permitted to do so.

Poor distribution of cattle and lack of uniformity of sheep grazing on the individual allotments, next to too early grazing by cattle, are the important causes of overgrazing at the present time. The range assigned to a given number of cattle or to a band of sheep in most cases will provide them with sufficient forage. The difficulty lies in getting them to use fully the more remote, least accessible

portions of the range without abusing the portions more easily reached. This difficulty can be overcome or minimized by improved methods of salting, herding, fencing, and development of water, as discussed in detail under the heading, "Management of Cattle on the Range." If these means are not successful, the number of cattle should be reduced. To prevent waste of feed which the cattle will not use, common use may be necessary.

More uniform use of sheep allotments is possible only through conscientious effort on the part of local forest officers, sheep owners, and herders to bring this about on all parts of each allotment. Without this the only way to remedy overgrazing is to reduce the number of sheep.

Overstocking undoubtedly was one of the main causes of the rapid deterioration of many ranges before they were placed under regulated grazing. It is believed, however, that most of the range units within the National Forests will support the stock now allotted to them if the grazing periods, distribution of stock, and the methods of handling the stock are reasonably well adjusted. If careful consideration of a recognized case of overgrazing shows that these factors are properly adjusted and overgrazing is still going on, then a system of deferred grazing should be applied; and, if effective carrying out of the system demands it, the number of stock should be reduced. Where overgrazing has resulted in denudation and erosion which has reached the stage of shoestring gullying, no grazing should be allowed until the damage is largely repaired and the cover of vegetation restored. To temporize in such cases in order not to disturb the local stock industry will hurt the local industry in the end, as delay increases the total protection necessary to build up the range.

Improper handling of stock on the range causes overgrazing, partly through lack of proper distribution. There are, however, a few features of improper handling which may result in severe local overgrazing on range where the stock are reasonably well distributed over the allotment as a whole. For example, though all portions of a sheep allotment may be used, the practice of bedding sheep six or more nights in the same place over a period of years will result in an area of from one-eighth to one-fourth of a mile around the bedding ground being overgrazed, sometimes disastrously.[1] The three-night bedding rule will help to overcome this difficulty, but will not entirely do away with it if three nights in the same camp, year after year, accompanied by trailing out from and back to the camp in late morning and early evening hours, is the rule rather than the exception. If one-night bedding, with the sheep away from the bed in

[1] Sampson, Arthur W., "Plant Succession in Relation to Range Management," U. S. Dept. of Agriculture, Bul. 791, 1919.

early morning, is the rule, and three-night bedding the exception, damage can largely be avoided. Overgrazing in spots by sheep occasionally results from shading up for hours during the day on areas where timber is scattering. The lack of shade results in the use of the same shade ground to excess. The remedy is to follow conscientiously the bedding-out system of handling sheep and to take care that no area is used to excess.

Cattle range may be provided with watering places and salt grounds which will largely eliminate local overgrazing. However, careful study is essential to locate salting grounds so as to help correct the tendency to excessive use of saddles, or natural passes, and flats, which at best will be used more than the average of the range. Care in distributing the cattle over the range when they are first put on and riding during the grazing season to keep them distributed will help much.

In the handling of goats the general principles outlined for the handling of sheep will serve as a guide. For more complete information Department of Agriculture Bulletin 749 [1] should be consulted.

UNDERGRAZING.

A general failure to secure full utilization of forage where a range is accessible is usually due to an insufficient number of the class or classes of stock to which the range is best suited. One class of stock might utilize fully the forage suitable to them, while forage suitable to another class of stock was being wasted. Additional stock of the class on the range would result in overgrazing. The solution is common use by the classes of stock to which the range is suited.

Localized undergrazing in most cases is due to lack of proper distribution of cattle or to failure to secure uniform use of the range by sheep. The remedies are, first, to make sure that the allotment boundaries are located so that full utilization is feasible, and then to work for the desired distribution of stock and uniform grazing by improved salting plans, water development, fences, bridges, stock trails, and riding.

GRAZING-CAPACITY ESTIMATES.

The grazing capacity of a range unit over a period of years is greatly influenced by the extent to which the suggestions given under overgrazing and undergrazing are applied.

AREAS OF NO GRAZING VALUE.

The area of no grazing value within range units and within National Forests varies from zero to over 50 per cent of the total

[1] Chapline, W. R. "Production of Goats on Far Western Ranges," U. S. Dept. of Agriculture, Bul. 749, 1919.

acreage. It is made up of (1) areas which produce no vegetation palatable to stock or so little that its use for grazing is not feasible; (2) areas which produce forage, but on which grazing is not practicable because of fallen timber, ruggedness, or too dense timber or brush; and (3) areas of good range, inaccessible because the cost of making them available for use is unwarranted by the value of the forage to be secured.

Where the lands of no grazing value are in one body it is not difficult to exclude them in estimating grazing capacity. More often, however, they are distributed in small areas, or small areas of grazing value occur along drainage within larger waste areas. The outstanding fact is that lands of no grazing value may exist in sufficient area to make figures for grazing capacity of a unit or Forest on an acreage basis meaningless until these lands are excluded from the estimates.

The first problem in estimating grazing capacity of a large Forest or of a large range unit, therefore, so far as there is a first problem, is to get at the acreage which supports forage and can be grazed. A range classification of the Medicine Bow Forest, for example, shows that 246,458 acres out of a total of 469,786 are not suited to the grazing of domestic stock. Pending a reconnaissance survey, advantage should be taken of every opportunity in connection with range inspection and range administration to secure similar figures for other forests. On many Forests the data must be collected in this way if it is to be secured in a reasonable length of time.

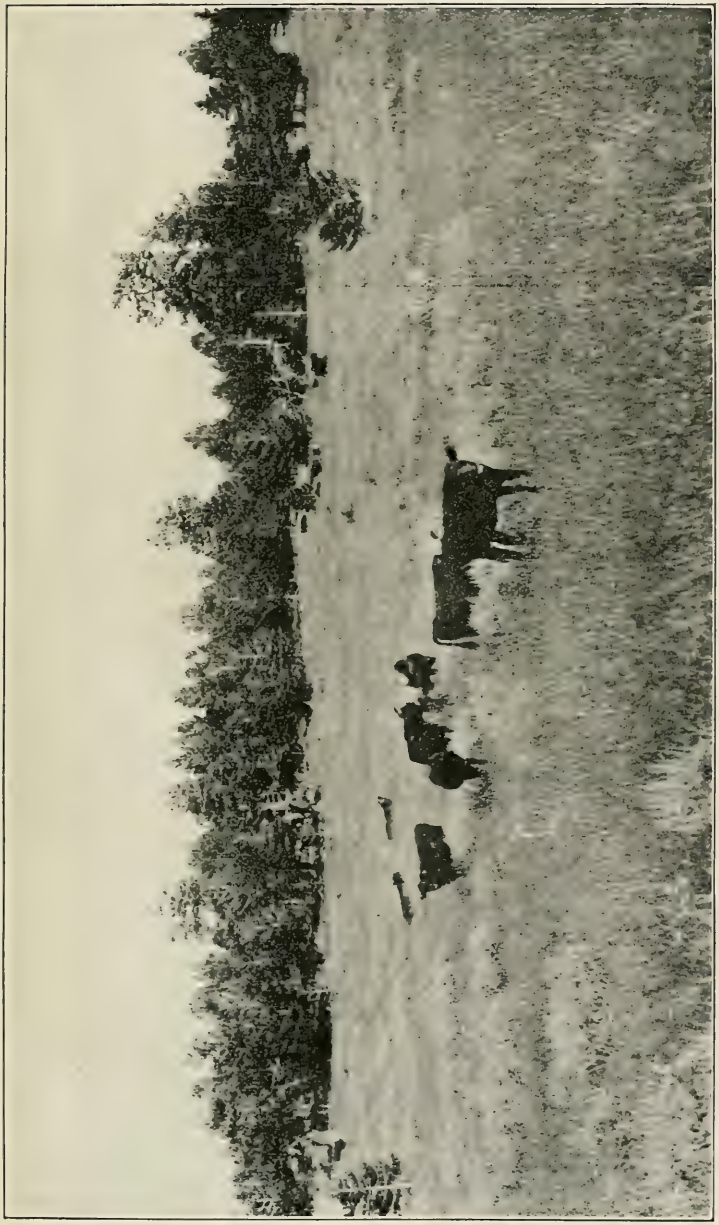
VARIATION IN AMOUNT OF FORAGE PER ACRE.

Variation in the amount of forage per acre on the land actually used for grazing may be so great as to require from 10 acres to 100 acres to support a cow throughout the year. Such extremes rarely occur on ranges of the National Forests after the area of no grazing value is excluded from the estimates. A variation of 100 per cent, however, not infrequently exists on a single unit. This fact confronts the range examiner in making grazing-capacity estimates after he has excluded acreage of no value for grazing.

If forage production, or grazing capacity, were always uniform over any considerable acreage, close approximation in estimates would not be exceedingly difficult; but on the rugged mountain ranges variation may be frequent and great on account of abrupt changes in altitude, exposure, slope, soil, and moisture. The solution of the problem is not obvious.

VARIATION IN AMOUNT OF FORAGE IN DIFFERENT YEARS.

Areas within the National Forests generally are not subject to the great variation in forage production which may occur on desert and



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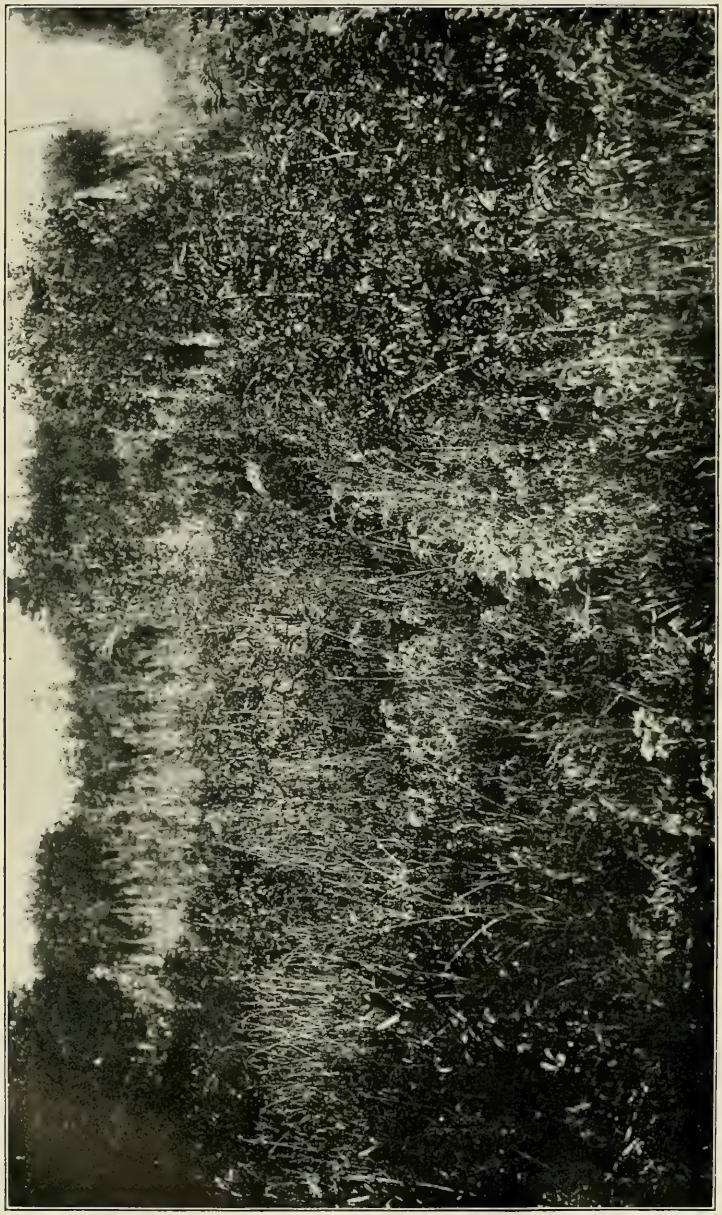
This condition of forage at or near the close of the summer grazing season indicates that the range is understocked. The remedy is more stock of the class to which the available forage is best suited.



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Local undergrazing, as in this case, often is due to poor distribution of stock on the range. Part of the range unit may be overgrazed and forage going to waste on other portions. Better distribution of stock is the remedy for both overgrazing and undergrazing in such cases.

semidesert ranges. That there is considerable difference in the quantity of forage produced in good years and in years unfavorable to plant growth, however, is certain. Estimates of grazing capacity should be based as nearly as possible upon forage production in average years. If this is done the occasional years of low forage production can be tided over without unwarranted injury to the range. If necessary, the stock can be removed a little earlier than in average years. Stockmen usually will do this of their own accord. The good years will serve to keep the vegetation up to standard by more vigorous growth and perhaps by natural reseeding. Surplus forage can be used by allowing the stock to remain on the range longer at the close of the season where weather permits. Where the grazing period is long and it is obvious at an early date that there is going to be an abnormally good forage crop with a surplus of forage, additional stock might be accommodated for temporary grazing to rest ranges at lower altitudes. The essential point is not to be led astray in grazing-capacity estimates by either the low forage production in poor years or the high forage production in years above the average. The small surplus of forage at the close of the grazing season should not occasion uneasiness on the part of forest officers. Slight understocking is far better for both the range and the stock than overstocking, however small.

RELATIVE PALATABILITY OF FORAGE PLANTS.

The palatability of the plant species which make up the available forage on a range is an important factor in the division of range between different classes of stock. Division of range, however, on the large mountain areas must be along rather broad lines and not on the basis of a few head. If common use is resorted to, and sheep are placed on cattle range to utilize weed feed unsuited to the cattle, there must be enough of this feed to accommodate a band of sheep, perhaps a minimum of 1,000 under present practice in range sheep management. Proportionately smaller numbers of cattle might be placed on a sheep range, but they would not travel over all parts of the range and use the forage unsuited to sheep. At best, then, there may be, and usually will be, a portion of the least palatable forage unused. The quantity will vary with the proportion and distribution of forage low in palatability. If it dominates on areas large enough to warrant use by another class of stock, common use may result in close utilization. If the forage of low palatability to the class of stock grazing is distributed throughout the range, little use can be made of it without overstocking.

This factor in estimating grazing capacity is emphasized here as a measure of precaution, because ranges have at times been reported as not fully stocked when vegetation of low palatability was left at

the close of the grazing season. No doubt grazing capacity of other ranges has been overestimated on this account and the number of stock increased, to the detriment of the range.

CONDITION OF THE STOCK.

Whether grazing capacity of National Forest ranges should be adjusted to produce fat stock or stock suitable for the feed yards is sometimes in question. The answer depends upon the character of the range and the demand for range to take care of stock for which feed is available locally for the remainder of the year.

Some National Forest range does not furnish forage suitable for producing fat stock in the sense of stock ready for the beef and mutton market, unless the range is so much understocked that the animals graze largely upon the choice forage and leave the rest. In the stockman's term this is "topping the range." On some ranges the combination of forage, water, salt, and topography may be such that the dry stock will become fat when the range is stocked as heavily as it should be, provided the beef stock are removed before the last part of the season when the forage is getting low.

Where more stock are produced and properly provided for during the remainder of the year than can be taken care of on the summer ranges, it is doubtful economy to deprive part of them of range in order to produce maximum gains on others. To stock a range so heavily as to retard the growth of young stock and keep the majority of the breeding stock thin would be unfair to the stock owners and dangerous to the range. If by "feeders" is meant stock in good flesh at the close of the season, the policy of grazing to produce feeders may be justified under conditions where local demand for range and the supply of fall, spring, and winter feed are in excess of available summer range, provided the surplus feed can not be disposed of to advantage except by feeding it to live stock grazed on near-by range. In general, continued stocking of a range so that the stock will come off in poor condition, due to shortage of forage, will result in deterioration of the range. The whole question has dangers, and decision should be made only after careful consideration, keeping in mind first the permanent welfare of the range. Ordinarily, the best policy is to stock the range so that beef and mutton will be turned off in the fall unless the range is of a character not suited to producing fat stock.

EFFECT OF GRAZING UPON TIMBER GROWTH AND WATER SUPPLY.

Grazing-capacity estimates may have to be adjusted locally to avoid unwarranted damage to timber reproduction or to a watershed on areas where exclusion of grazing is not deemed necessary, but where the possibility of unwarranted damage is greater than for the

range as a whole. The main precautions necessary and the reasons for them are presented on page 66.

ACREAGE REQUIRED FOR SHEEP AND CATTLE.

A number of grazing-capacity studies have been conducted to determine the minimum acreage required to support a cow or sheep through the grazing season. The acreage grazed over, the intensity of grazing, the length of the grazing season, and the methods of management of both range and stock have been closely observed and recorded by men giving special attention to the work. To supplement these special studies, the data secured from grazing reconnaissance surveys during the past six years have been carefully analyzed. The data from the two sources appear to be consistent enough over a wide range of territory to warrant conclusions as to the approximate average acreage requirement for cattle and for sheep. It is believed that the figures which follow will be of material value in bringing about greater uniformity in the quantity of usable forage made available for each animal or for each band or herd over individual Forests and over the Forest ranges as a whole. It is not intended that they should apply to a small range unit or part of a unit with the accuracy finally desired. The first big step, however, in adjusting grazing capacity is to equalize the distribution of forage and stock over large units. After this is done the final grazing capacity on individual ranges will have to be worked out by adjustments from time to time over a period of years until the number of stock is such as to utilize all the forage as closely as it should be used on the individual range, all factors considered.

ACREAGE FOR SHEEP.

Fifty-six sheep allotments on summer range have been carefully studied during the past few years. An average of 2.5 acres, or 0.79 forage acres,[1] was required to support 1 mature sheep or 2 lambs

[1] The variation in amount of forage per acre and the relative palatability of forage plants are important factors in determining the amount or volume of forage which stock can be expected to use on a given range, and consequently in determining the grazing capacity of the range in question. To determine the comparative amount of forage by range reconnaissance methods, the range is classified into types, and for each area of a given type the stand of forage which stock should use is estimated. A complete ground cover made up of vegetation palatable to stock is represented by 1.0. Variation from this standard is represented by the decimals 0.95, 0.90, 0.85, and on down to 0.1. The actual acreage of a given area multiplied by the decimal representing the stand of forage gives the amount of forage which it is estimated that stock will secure. For example, on an area of 100 acres, where the forage factor is estimated at 0.5, there are 50 units of forage produced. The unit of measure in this case is called a forage acre, and in the example given there are 50 forage-acre units on the 100 surface acres of range. This method of arriving at the grazing capacity of range is not in general use and therefore is not emphasized in the text. It is used, however, by grazing experts who have been trained in range reconnaissance surveys and estimates, and for this reason the forage-acre requirements of range stock are given.

for an average grazing period of 72 days. The figures do not include lands of no value for grazing.

The ranges studied include sheep allotments on choice summer range of Montana, inferior timber and brush ranges of Idaho and Utah, and ranges of about average value in these States and in Oregon and Wyoming.

The sheep under observation were all ewe and lamb bands. Two lambs were considered the equivalent of one mature sheep. The bands contain an average of 58 per cent of lambs. The ratio of two lambs to one mature sheep is an arbitrary one, since no data are available to show the relative forage consumption by lambs and by their mothers on summer ranges. To use this ratio, however, and include the lambs is better than to disregard the lambs, because the percentage of lambs may vary greatly.

The average lamb crop for the far western range States as given by the United States Tariff Board[1] is 70.3 per cent, with Washington the highest at 92.5 per cent and Arizona lowest at 59.3 per cent. The general average has probably been increased slightly since this report was issued, so that to figure on a 75 per cent average lamb crop in using the grazing-capacity figures given will be within the general margin of accuracy and uniformity of grazing estimates and methods.

If such a thing as a uniform measure of grazing capacity can be used, it would appear from close study of the tests conducted, and from similar figures deduced from range reconnaissance surveys, that 0.01 forage acres per head per day is about right for range suited to sheep grazing. This would be equivalent to about 0.03 surface acres per head per day, exclusive of range having no value for grazing, or about 3 surface acres for a grazing period of 100 days.

ACREAGE FOR CATTLE.

A high, open, rolling range on the Lewis and Clark National Forest in Montana supported one cow to every 7.37 surface acres, furnishing 2.65 forage acres per cow for a period of 100 days. This is at the rate of 27 surface acres, or 9.69 forage acres per year.

On cattle ranges of southern Idaho 10 surface acres, furnishing approximately 4 forage acres, was found to be the minimum required for one cow over a period of five and one-half months. This range is well watered and was closely utilized.

Good grass foothill pasture of the Santa Rita Range Reserve in southern Arizona has furnished an average of 365 cow-days' feed annually over a period of years on an average of about 14 acres. Each year during the main growing season the number of stock was

[1] U. S. Tariff Board, Wool and Manufactures of Wool, Vol. II (pt. 2). H. Doc. No. 342, 62d Cong., 2d sess., 1912.

reduced about 30 per cent below the average for the year, to give the vegetation a chance to grow. Otherwise, grazing was yearlong. Utilization was closer than can be expected on open range.

Studies of grazing capacity on the Jornada Range Reserve in southern New Mexico led to the conclusion that the grass range will support one cow on 20 to 30 acres, depending upon the acreage of poorer range types which occur within the grass type.[1] These figures are computed on a yearlong basis, but with the understanding that the number of stock will be reduced during the main growing season, July to October, to about one-half the average number for the year. With the relatively close utilization possible under fence on the Jornada Range Reserve it is figured that approximately 8 forage acres per cow yearlong will be sufficient.

In general, the grazing-capacity figures indicate that about 2 to 2½ acres per cow per month is as near an average as can now be arrived at for cattle range suited to this class of stock within the National Forests. This, of course, is the acreage required exclusive of lands of no value for grazing except the occasional small patches of waste within usable range. With this average as a guide, the examiner can judge whether range is exceptionally good or inferior and can adjust his estimate accordingly. Where available forage is estimated in terms of forage acres, an average of about 0.8 forage acres per cow per month should be allowed. If utilization is complete and close over the entire area, as it usually is in pastures, 0.7 of a forage acre, or a little less, per head per month should be sufficient.

COMPARISON OF ACREAGE REQUIRED FOR SHEEP AND FOR CATTLE.

Considering the general difference in the forage suited to sheep and cattle, it is evident that there is no constant relation between the grazing capacity of a range for sheep and the grazing capacity of the same range for cattle. By careful division of the range between different classes of stock, as outlined on page 3, the justification for change in class of stock on a general range is largely done away with. Some ranges, however, may be used to advantage by either sheep or cattle. A change from one class to the other can never safely be made in an individual case on a previously decided or fixed ratio. The ratios used in the Grazing Manual of the Forest Service[2] are based on general averages and are intended for application to the special case of change in class of stock, provided the grazing capacity of the range in question for the new class of stock warrants the use of the standard ratio. The grazing capacity of the range in question for

[1] Jardine, James T., and Hurtt, L. C., Increased Cattle Production on Southwestern Ranges, U. S. Dept. of Agriculture, Bul. 588, 1917.

[2] U. S. Forest Service. National Forest Manual; Regulations and Instructions, Grazing Section.

the class of stock to be allowed by the change should be determined by careful inspection of the range.

GRAZING CAPACITY AS AFFECTED BY MANAGEMENT OF THE STOCK.

The grazing-capacity figures given apply to conditions of average management as regards distribution and control of cattle and herding of sheep. It should be remembered that with poor distribution of cattle or close herding and driving of sheep to and from a central camp from 10 to 20 per cent more range will be required, depending upon the extent of poor management. On the other hand, a decrease of 5 to 15 per cent from the average figures should result from an approach to the ideal in management of the stock on the range. How to approach the best that can be expected in the handling of stock on the range is explained in later paragraphs on cattle management and sheep management.

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MANAGEMENT OF CATTLE ON THE RANGE.

Control over the numbers and distribution of stock is a fundamental requirement of regulated grazing and effective range management. Many of the difficulties involved are brought out in the preceding pages because the action recommended there is often directly dependent upon this control. In turn, the discussion which

follows applies to the management of cattle after the range has been divided among different classes of stock, the grazing period fixed, and the grazing capacity decided upon in accordance with the suggestions given.

CONTROLLING THE NUMBER OF CATTLE.

Until the number of cattle actually grazed and the period of grazing are the same as the number and period authorized, the most efficient use of the range is not assured. This applies not only to a National Forest as a unit, but to each subdivision of the Forest which is considered as a unit of management. A National Forest as a whole may not be overstocked, in fact, may be understocked, and yet large subdivisions of it may be overstocked. The problem, then, involves control at the boundary of the Forest and control by individual units within the Forest.

CONTROL AT FOREST BOUNDARY.

Lack of satisfactory control of cattle at the boundaries of Forests has resulted in both premature grazing and overstocking on nearly every National Forest where cattle are grazed in large numbers. The main difficulty lies in the fact that with few, if any, exceptions there is unfenced range adjoining the Forest lands.

In localities where the stock are fed during the winter they usually are turned on the open range soon after the snow is off and later drift on the Forest land before the range should be grazed. If the number turned out is in excess of the number the Forest range will support, it is almost certain that the Forest range will be overstocked at some time during the grazing season.

In a great many cases "on and off" permits are issued to cover cattle which graze a range unit part of which is outside of the Forest boundary and part inside. The range outside may have a grazing capacity equal to the area used inside. The Forest range, however, is usually higher in altitude, and in a great many places the forage and water facilities are better than on the adjoining lands outside. As a result, the stock will naturally use the range on the Forest more than the range outside. To issue an "on and off" permit on the basis of 50 per cent of the grazing to be on the Forest and 50 per cent off does not remedy the situation. Nor will it be remedied by issuing a permit for 75 per cent of the stock on the Forest, as this would authorize overstocking.

The most effective remedy is to fence the Forest boundary. All Forest boundaries, however, can not be fenced in the immediate future. In the meantime, measures should be taken to protect the range. In some instances the grazing can be equalized by proper distribution of salt, salting heaviest on the outside range if necessary, and by riding to help keep the stock distributed.

Each local case where control of cattle at the boundary of the Forest is involved may have its peculiarities. In all, however, close cooperation between forest officers and the owners of the stock is imperative to secure good results. Forest officers should take the lead and work out some plan for proper use of the Forest ranges. Difficulty of adjustment should not stand in the way of action, because the construction of fences is always a possibility.

CONTROL BY RANGE UNITS WITHIN A FOREST.

With assured control of the number of stock entering the Forest and of the time that they enter, there still remains the big task of control to secure distribution so as to equalize grazing, prevent straying and loss of stock, and minimize the riding necessary and keep it at least within practical limits. Consequently, it is necessary to divide the cattle range within a Forest, or, for that matter, any large area of cattle range, into smaller units of management. What shall be the basis of this division, all factors considered? The importance of this question and its bearing upon future management of the range and stock are not always appreciated.

A number of important, somewhat conflicting, factors are involved:

1. To secure maximum production of stock on the range over a period of years some form of deferred and rotation grazing is imperative. Any plan for control of stock by units should provide, therefore, for deferred and rotation grazing eventually.

2. The segregation of breeding stock from dry stock on the range is an important item in the production of beef and will help to increase the calf crop.

3. Frequently there is great range in altitude and consequently great variation in the time at which different parts of the range on a single watershed should be grazed. Consequently, as pointed out in the paragraphs on period of grazing and natural reseeding, provision should eventually be made for dividing late spring and early summer range from midsummer and late summer or early fall range.

4. Boundaries of comparatively large units on ranges within the National Forests can usually be chosen so as to take advantage of natural barriers, high ridges, and streams and thus minimize the fencing necessary to control the stock. On the other hand, distribution of stock is easier to obtain on small controlled units than on large units.

5. Individual owners of stock naturally prefer to run their stock separate from that of other owners, and in many instances are prepared to construct fences for this purpose. Units to take care of individual permittees, however, interfere with proper management

of the range and stock as a whole, except where the range of the individual is clearly a distinct natural grazing unit.

6. As a rule, the range lands are low in grazing capacity compared with farm pastures. Consequently, the number of stock controlled, rather than the acreage controlled per mile of fence, usually decides whether the cost of fencing is warranted or not. The exceptions are fenced areas for holding beef stock while they are being gathered, for pure-bred registered stock, for weaning calves, and for saddle stock.

It is obvious that these important factors can be incorporated in the final plan of management only by looking ahead and working out a comprehensive plan for the development and use of the range. Otherwise a beef pasture, calf pasture, or individual fenced range of to-morrow will interfere with segregation of breeding stock and dry stock, or with divisions for proper seasons of grazing, or deferred and rotation grazing next year or later.

As a matter of fact, the features of management outlined in numbers 1, 2, and 3 are becoming more and more important and should be given first consideration in working out plans for future control and management of the range. To insure the incorporation of these principles in the management of the range and stock on lands of low grazing capacity necessitates management by comparatively large units, otherwise the expense of the necessary control will be unwarranted.

On ranges within the National Forests the division of cattle range into units should ordinarily be by watersheds, where practicable, in order to take advantage of topographic features which will aid in controlling the stock. Watersheds, however, are not always satisfactory units. They may be too large or too small for effective management. It is difficult to define what too large or too small means as regards acreage; for variation in altitude, in topography, in the shape of the area, and in the character of forage and cost of controlling the stock are important. Ordinarily, however, a unit which will support not more than 3,000 head nor less than 1,000 head of cattle should be satisfactory. There will be individual units larger, and some smaller, which clearly should be managed as units.

Just where the division lines should be is often influenced by community interest. It is obvious that cooperation of permittees in the handling of the stock and the range is necessary to successful range management. So far as practicable, therefore, the cattle units should be such as to group the stock by communities, so that it will be possible for the owners to organize into an effective, active stock association with unity of interests. This factor is of increasing importance as range management becomes more intensive. The grouping of community stock, therefore, in many cases may be of sufficient im-

portance to warrant variation from what would seem to be the most desirable natural unit range division, so far as topography is the deciding factor.

The important feature of this whole question of cattle units is to look into the future and plan with a view to the management desired, rather than to act "piecemeal" from day to day on separate phases of management. A comprehensive plan of management embodying the principles outlined will be a necessity in the not-distant future. Such a plan, to be lasting, should be by units which will remain permanent, as far as this is practicable. The community unit for cattle range, conforming to natural topographic divisions, appears to offer the greatest possibilities for permanency and for comprehensive plans of range development and management which will make possible, eventually, the application of fundamental principles of range and live-stock management, and yet be practicable as regards cost, both for development and for administration. The personnel of the users may change, but the unit and its management should not.

As soon as such units are established with assurance of reasonable permanency, constructive work should begin on means of preventing drift of stock from one unit to another. As in the case of control at the boundary of the Forest, the final control by units will be obtained by a combination of fences and natural barriers. Pending the construction of necessary fences, however, reasonably effective control of stock can be secured by care in salting, watering, and riding to get the stock accustomed to their home range. Cattle once thoroughly accustomed to using a given range are not inclined to drift far. Stock placed on a new range and young stock born on the range must be carefully watched during at least one year to prevent drift. Salt should not be placed near the dividing line between two units; stock should not be driven from one unit to another during a round-up; if they are moved they should be returned to their home range; if a few head of stock become accustomed to drifting from one unit to another they should be got rid of as soon as practicable, as one old cow may lead a number of young stock off the range and cause unwarranted expense for riding and loss from straying.

DISTRIBUTION OF CATTLE WITHIN A UNIT.

Once range-management units for cattle are established and the numbers of stock and period of grazing are under control on each unit the problem is to secure the best use of the forage on the individual unit. This involves grazing at the proper time, as well as full, uniform grazing over all parts of the unit. The means of arriving at both these ends are proper salting of the cattle, development of watering places, construction of fences, construction of stock trails, and attention by riders.

SALTING.

Proper salting of cattle alone can not be expected to correct all of the natural faults in distribution of cattle on a range, but, everything considered, salting offers the greatest possibilities for bringing about immediate improvement throughout cattle ranges within the National Forests. This is due in part to the feasibility of working out and putting into application improved salting plans without delay. While water often is not to be had where it is desired, the proper location for fences is uncertain, and both water development and fence construction involve great expense compared with salting. There is no more immediately important grazing work, therefore, to which a forest officer may devote his time than securing proper salting of the cattle on range units under his supervision.

Amount of salt.—Cattle should have from 1 to 2 pounds of salt per month while on the range, ordinarily 2 pounds per month while the vegetation is succulent and 1 pound per month during the remainder of the season.

Kind of salt.—Crystal sack salt, compressed salt, and rock salt are used for cattle on the range. Stockmen differ in opinion as to which of these kinds is best for the cattle and most economical. Crystal sack salt, usually called stock salt or coarse salt, as distinguished from dairy salt or fine salt, appears to be gaining in popularity. It can be distributed so that many cattle can get salt at one time, while a large block of rock salt may be monopolized by one cow for an hour or more. Care must be exercised, of course, to prevent cattle exceedingly hungry for salt from having free access to such salt troughs.

Salt containers.—Sack salt fed to cattle on the range is generally placed in long troughs, in wooden boxes, on rocks, or on the ground. The practice of using salt logs or salt boxes is rapidly growing and no doubt will be general within a few years. Where logs are available on or near the salting place selected, the log-trough container is the most economical and most satisfactory, all things considered. A log large enough so that the top will be about 30 inches above the ground is best for cattle. The animals will then feed from both sides; more animals can feed at one time than at a smaller log; and there will be less crowding and less chance for the salt to become foul. Where logs are not readily available, salt troughs made of lumber are used extensively. Where transportation is not difficult troughs can be made in town or at the ranch when labor is not occupied at other work. This is sometimes an advantage over log troughs, which must be made on the range when other work may be pressing.

Figures 1 and 2 show sketches of salt logs and salt troughs which have given good service.

Distribution of salt.—Salting places should ordinarily be located so as to draw the cattle away from watering places and other areas where they naturally congregate and overgraze the range. Where new dirt storage tanks have been built it may be advisable to depart from the general rule and salt at the tanks temporarily, so that the stock will tramp the bottom of the tank and thereby help to make it hold water. The main object should be to secure uniform utilization of range between salt and water over the entire range unit. The distance of salt from water will depend upon water distribution and topography. No set rule can be laid down. The problem must be worked out on the individual range unit so as to secure the most uniform grazing possible and limit as far as practicable congregation of stock and overgrazing around water holes, salt grounds, and

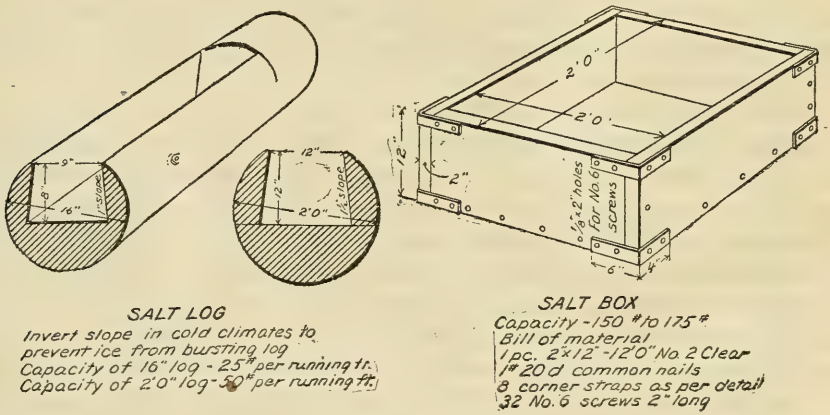


FIG. 1.

natural passes. Ordinarily, salting places should not be more than 1 mile apart, and occasionally salting places well chosen at distances less than 1 mile apart will result in the use of range which otherwise would not be grazed until the more accessible parts are overgrazed.

The amount of salt for any salting place should be based upon the grazing capacity of the range to be used from the salting place. If, for example, such a range is expected to support 50 cattle for one month early in the season, the amount of salt put out should be 100 pounds, or for the same range late in the season, 50 pounds. The amount of salt for each salting place should be worked out on this basis. If it does not conform to the grazing capacity of the range intensity of grazing will not be uniform.

The stockmen who use the range should cooperate in the selection of salting places. As nearly as possible the sites selected should be satisfactory to them. The deciding factor, however, should be the best use of the range and not the wishes of the users. The results

secured from proper salting will overcome many objections which appear to be well founded in the beginning.

Naming, numbering, and marking salt grounds.—Salt grounds are sometimes marked by a signboard bearing the name or number, or both. This is of advantage in formulating and following out a written salting plan. The cost of marking the many salt grounds which should be selected and used, however, would consume more time than is warranted for the present. Further, it is difficult to plan a system of salt grounds so that the site first selected will prove satisfactory in every case. Changes from time to time may be advisable as the system is perfected. There is a possibility, also, that the location of a salt ground may have to be changed occasionally to prevent unwarranted injury to the range.

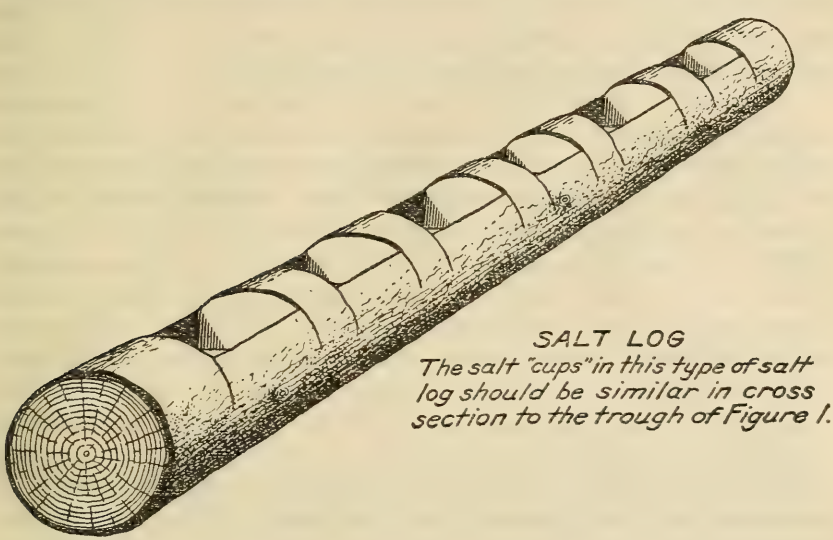


FIG. 2.

On the other hand, a system of salting places such that a written salting plan can be prepared and followed is essential in securing proper salting without unwarranted supervision. A few important salting places in each set might be marked by a signboard bearing the name and number, or just the number. These would serve as landmarks in describing and finding the other numbers of the series. Perhaps every tenth salt ground of a series might be marked by a signboard.

Time of salting.—Salting can be taken advantage of in controlling the time a given piece of range is grazed, and the schedule for time of salting should be prepared with this end in view. In the discussion of grazing periods it was pointed out that the beginning of growth in the spring is delayed from 7 to 10 days with each 1,000

feet increase in altitude and that there is considerable variation in the time when growth begins on different exposures at the same altitude. By carefully planning a schedule showing the date salt should be put out at each salting place, much can be accomplished in adjusting the time of grazing to conform to the requirements of the vegetation. The earlier range should be salted first, and salting at higher altitudes delayed in proportion to the delay in growth of the vegetation. To secure the best results, salt remaining at the lower altitudes when the range is fed out should be removed. Otherwise some of the cattle will remain near this salt and overgraze the range. Timely salting is facilitated by numbering the salting grounds to conform to the time the range should be used, beginning with number one at the earliest salt ground. A written salting schedule can then be prepared, dividing the season into periods by days, weeks, or months, and designating by numbers the salting places to be used during each period and the amount of salt for each place.

It is important that salt be placed on the range when the stock are put on. Care at this time to separate the cattle into small bunches and distribute them among the salting places over the range ready for use will do much to get the stock settled and secure uniform grazing.

Hauling and storing salt.—Roads and trails are usually in good condition late in the fall, but difficult to pass over, if not impassable, at the time the stock are put on the range in spring. Where this is the case sufficient salt to last at least until roads and trails are in good condition the next spring should be hauled in the fall and stored convenient to the range. This practice has been followed by some stockmen and stock associations. It should be adopted wherever local conditions make the practice advisable. Salt is most needed by stock early in the grazing season, and failure to provide it because roads are impassable at that time is not a valid excuse. Small cabins or salt-storage boxes can be provided without unwarranted expense.

RESULTS FROM PROPER SALTING.

A good example of what can be accomplished by proper salting of the range is afforded by results secured on a cattle range on the Minam National Forest in Oregon.

The cattle and horse unit in question includes about 40,000 acres of timber and open range. In 1913 it was grazed by 1,574 head of cattle and horses. The stock were salted at three or four places. Part of the range was overgrazed at the close of the season, and much feed was unused on other parts. The upper portion was little grazed by cattle. In 1914 the stockmen became interested in better methods of salting. Forty-four salt troughs were constructed, at a cost of $1.25 each, from logs 18 inches to 24 inches in diameter.

The average trough space for salt on each log was about 12 inches wide, 8 inches deep, and 12 feet long. In 1915 an additional 22 troughs were constructed, at a cost of $2 each. These 65 troughs are distributed from one-half to three-fourths of a mile apart over the range, and are numbered 1 to 66, beginning at the lowest altitude and extending consecutively upward. In 1914, when the first 44 salt troughs were established and systematic salting began, 1,774 head of cattle and horses were permitted to graze, as compared with 1,574 head in 1913; in 1915 about 2,100 head were grazed; in 1916, about 2,150 head; in 1917, 2,200 head; and the recommendation for 1918 was 2,250 head. The increase each year has resulted from better distribution of stock so as to utilize all the feed.

On this range a definite written salting plan is prepared before the grazing period opens each season. The date of placing salt at a given series of salt troughs is varied somewhat from year to year to give the forage plants on all parts of the range an equal chance to grow.

A salting plan for a large cattle unit on the Uinta National Forest is shown graphically in figure 3. This unit contains approximately 30,000 acres and has a grazing capacity of 1,880 head of cattle for a grazing period beginning May 15 and closing October 31. The plan calls for 8½ pounds of salt per head, a total of approximately 16,000 pounds per season.

The unit includes the entire watershed of Currant Creek. The area was first divided into smaller describable areas, and the grazing capacity of each of these smaller areas was determined in order that the distribution of salt might be proportionate to the distribution of cattle feed.

On brushy ranges of California the use of salt is an important feature in handling the cattle. In many places the range is so brushy that extensive riding to check distribution of stock, inspect the stock during the grazing season, and gather them in the fall is impracticable. This lack of extensive riding is largely offset by the use of salt. The rider follows the trails, ridges, and canyons or draws accessible by saddle horse and pack horse, and carries salt with him. He makes frequent stops over the range and calls to the stock. The cattle soon learn the meaning of this call, and come from the brush as far as they can hear the call. By proceeding systematically over a range unit in this way the rider can check the number and distribution, as well as the condition of the stock. No salting for perhaps three weeks before the final round-up will make the salt call effective in gathering the cattle without great difficulty. The work accomplished by this practice on brushy range convinces one that proper salting can be made a factor of great importance in securing

the desired distribution of stock on the ranges within the National Forests—a problem of major importance in the management of cattle ranges.

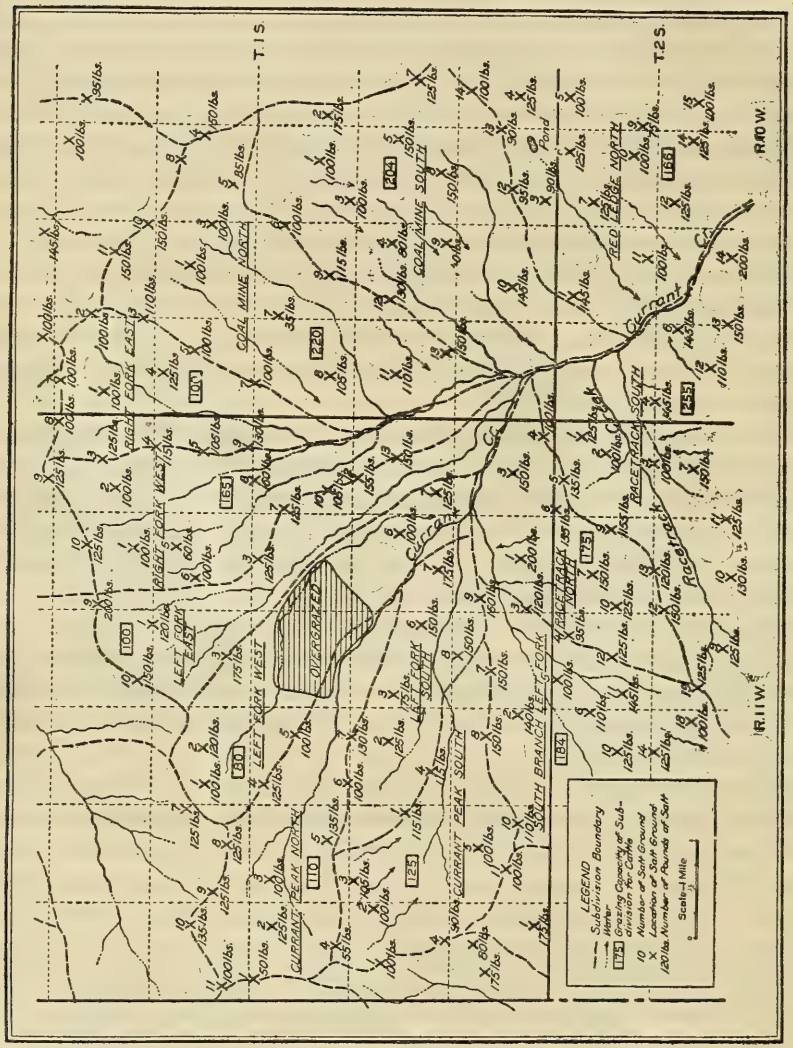


FIG. 3.—Graphic salting plan for a large cattle range unit on the Uinta National Forest.

SUMMARY ON SALTING.

The main points to remember in connection with salting cattle on ranges of the National Forests are:

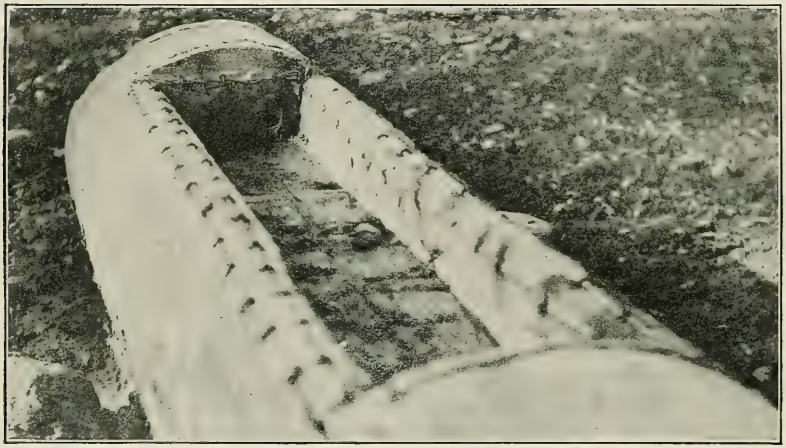
1. That improvement in salting probably offers the greatest opportunity for immediate improvement in the management of cattle ranges.

F-20504-A

Fig. 1.—Counting cattle as they go on a National Forest range. Until the number of cattle and the time that they go on the range are properly controlled, proper use of the grazing resources is not assured.

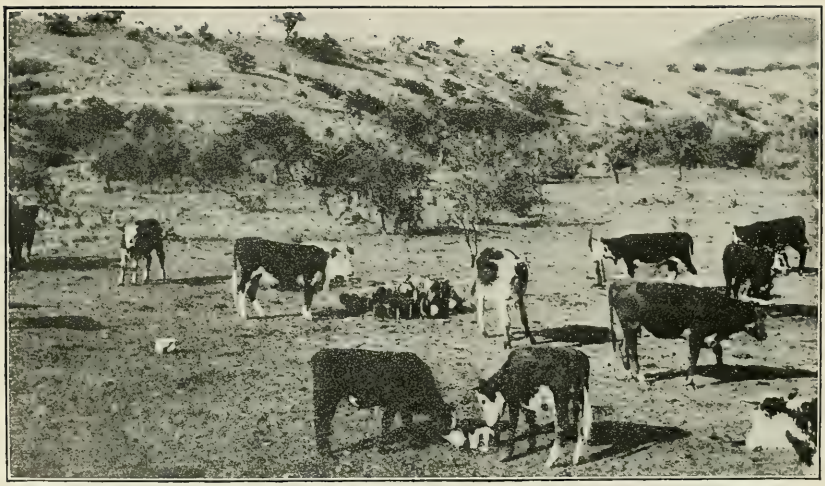
F-76674

Fig. 2.—Control of cattle by range units within a National Forest can be secured by a combination of fences and natural barriers.



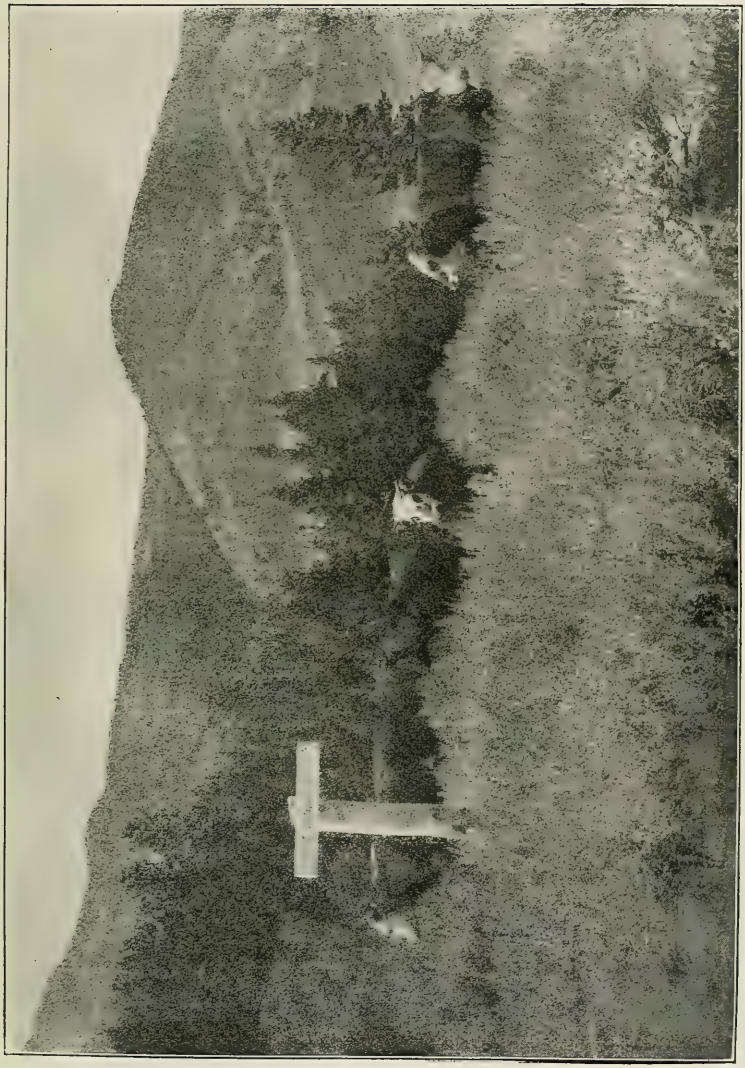
F-8-WRC

Fig. 1.—Salt log used on cattle range of Whitman National Forest. Smooth, twisted wire stapled every 4 inches is used, as shown, to protect the trough from gnawing by horses and porcupines.



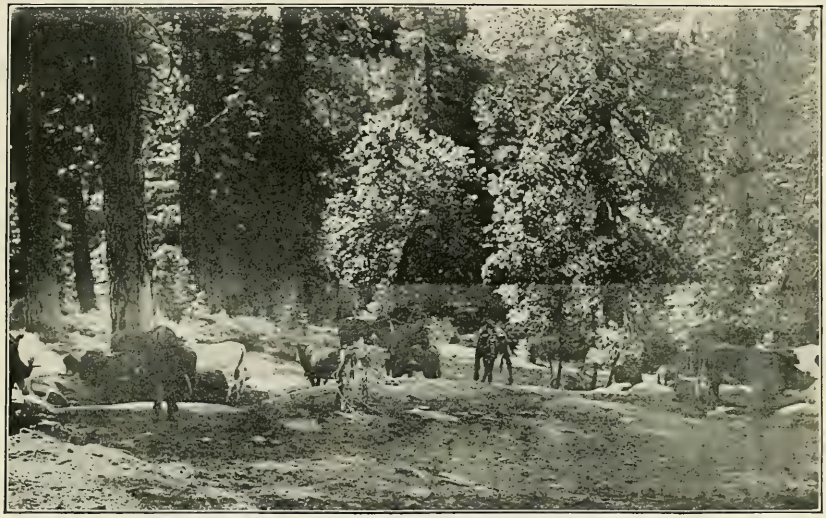
F-27212-A

Fig. 2.—Where block salt is used one cow may monopolize a block for an hour, forcing the other animals to wait their turn.



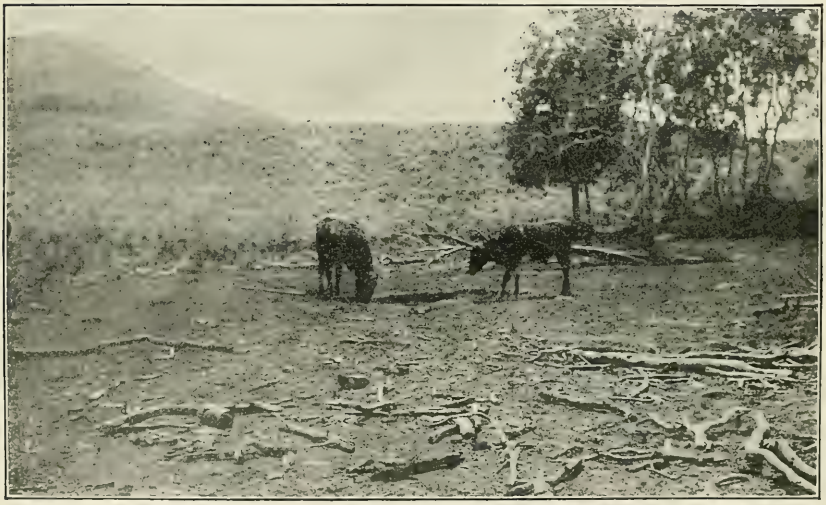
F—29392—A

Signboard marking a salt ground on the Sawtooth National Forest in southern Idaho.



F-19993-A

Fig. 1.—These cattle were called from dense timber and brush range and were fed salt on rocks, as shown.



F-9-WRC

Fig. 2.—The old type of salt ground. Salt should be placed on the ground only as a last resort.

2. That the responsibility for securing the proper salting of stock on any National Forest range unit rests directly upon the local forest officer in charge.

3. That cattle require ordinarily about 2 pounds of salt per month while the forage is succulent and about 1 pound per month for the remainder of the season.

4. That cattle accustomed to being salted will travel to salt as they will to water; and that salt, therefore, can be used as a means of securing distribution of cattle over the range.

5. That salt should usually be placed at a reasonable distance from water and away from places where cattle naturally congregate or pass frequently. Salting at new dirt tanks may be advisable until the tanks hold water.

6. That sack salt should be placed upon the ground only as a last resort. Log troughs or wooden boxes should be used wherever practicable.

7. That a few important salt grounds in a series, perhaps every tenth one, should be marked with a sign bearing a number or a name, or both.

8. That on range units with a considerable variation in elevation or exposure the salt should be put out at times corresponding as nearly as possible to the date the vegetation should be used, so as to discourage premature grazing.

9. The amount of salt for any salting place should be based upon the grazing capacity of the range to be used from the salting place.

10. That definite graphic and written plans, based on a thorough knowledge of range conditions, are necessary in securing a proper distribution of salt on almost any cattle range.

11. That only through the active organized cooperation of permittees can satisfactory results be secured.

WATER.

The distribution of water may influence the distribution of cattle and the utilization of forage more than any other single factor. Man's control over the distribution of watering places on the range, however, is limited. Frequently it is not possible even to approach the desired number or distribution. It is assumed in this chapter that the suggestions of the paragraphs on division of range between different classes of stock have been carried out. This discussion applies, therefore, to range reasonably well suited to cattle grazing.

The suggestion of importance is to look carefully into the available water supply, and, if possible, have a watering place every half mile on rugged mountain range and every mile and a half on level or rolling range.

Springs and seeps which naturally furnish water only in small puddles or cow tracks will furnish clean water for a number of cattle if the supply is developed and troughs installed. On ranges of the Southwest a large part of the water supply is furnished by storage tanks which collect and store surface run-off. This method of water development can be resorted to in other localities. Also, wells 500 feet deep or more, equipped with windmills and engines for pumping, are used successfully on large areas of range. In some places water for midsummer is obtained by collecting into storage tanks early in the season water from small meadow areas which dry up in midsummer. Range is valuable. It can not be used by cattle without water. It should not be considered permanently unusable until exhaustive consideration has been given to possible ways of water development. Farmers' Bulletin 592 [1] discusses methods of developing water for stock under range conditions.

FENCES.

Very often fences are the most effective and most economical means of controlling cattle on the range. In fencing, however, the first consideration should be given to fences to provide control which is vital to the range as a whole. The importance of such control, first at the boundary of a National Forest and then at the boundary of smaller natural range units, has been emphasized. Generally, control at these places, by fences if necessary, should come first, so as to control the numbers of cattle and time of grazing on the Forest, as a whole, and on the natural unit of management. With this control established, interior fence control should proceed according to a well-developed plan for the management of the cattle within the natural unit.

The important objects of fences within the unit are: To make possible seasonal grazing and deferred and rotation grazing, as outlined in the paragraphs on Grazing Periods and Natural Reseeding; segregation of breeding stock from dry stock; protection of cattle from poisoning; protection of areas of watershed, timber growth, or recreation areas from grazing; holding pastures for stock during a round-up; reserving pastures for saddle stock; and economy in handling the stock and in supervision of grazing. These possible needs should be considered in working out the fencing plan for each unit. Protection and the best use of the range resources should be given first consideration.

Several years ago a general study was made to ascertain the economic value of stock fences then in existence on the National Forests. Each of 243 fences was reported on. The average estimate of in-

[1] Barnes, Will C., Stock Watering Places on Western Grazing Lands, U. S. Department of Agriculture, Farmers' Bul. 592, 1914.

crease in grazing capacity due to the fences was about 15 per cent. The reported improvement in condition of stock, due to more quiet handling under fence, averaged about 5 per cent; the increase in calf crop, about 10 per cent; and the decrease in cost of handling, 40 per cent. Aside from these important items the fences as a general rule simplified and reduced the cost of grazing administration, reduced trespass and complaints, and resulted in more even utilization of the range.

These data were included to give an idea of the possible increase in net returns as a result of stock fences where they are warranted and properly located. Too often, however, fences for minor purposes are constructed and later interfere with the fencing plan for management of the unit as a whole. It is extremely important that the plan for the whole natural range unit be worked out before any great amount of piece fencing is undertaken.

TRAIL IMPROVEMENT.

On many ranges used by cattle for years the construction of a few stock trails would help to produce a few more and better stock by opening to use small areas now inaccessible or difficult for stock to reach, or by providing a trail to water. These are minor developments which will come in time.

RIDING.

The stock on any range cattle unit need the attention of riders. Proper salting, water development, fences, and stock trails work wonders in the management of cattle on the range and consequently increase grazing capacity. After all that reasonably can be expected by these means is accomplished, however, there is still room for improvement. This is due mainly to the fact that in range management we are dealing with large areas, usually of low grazing capacity, and on such lands the extent to which improvements can be made is limited both by natural conditions and by expenditures proportionate to the value of the forage. When this limit is reached the subdivisions of the range are very large as compared, for example, with the subdivisions of a well-developed ranch.

The riders should see that salt is always available, and that watering places and fences are in serviceable condition. After this they should see that the stock are kept well distributed and that they use all parts of the range. Occasionally it is necessary to herd stock away from dangerous poison areas, and attention may be needed to keep the bulls properly distributed with the breeding cows. Losses from any cause should be watched for, the cause determined if possible, and preventive measures taken. Carcasses of dead animals should be burned or buried as a protection to the health of remaining animals.

Ordinarily, too little attention is given to the stock for the best results in growth, calf crop, and losses. A few pounds additional weight on the beef animals, an additional calf from each 100 cows, and one or two additional cows saved out of 1,000 head will more than pay for the services of riders. On most cattle ranges these increases are the minimum that can be expected. An increase of 100 pounds or more on beef animals, an increase of 5 calves for each 100 cows, and a decrease of 10 head in loss out of each 1,000 head, in addition to increase in grazing capacity of the range, are nearer the possible net returns from proper attention by riders. Animals are valuable, and costs of production are increasing. It will pay to figure carefully on the possible returns from an additional dollar invested.

The number of stock one rider can look after varies from about 250 to 1,000 head, depending upon the range. The ideal to work toward is about 250 head of high-grade stock accustomed to being worked. One man can then distribute the stock in small bunches where feed is best, see that bull service is adequate, and look after the general welfare of the stock so that losses will be negligible and net returns per animal a maximum. Plate XXIII, figure 2, shows an actual example of such management on National Forest range.

BREED OF STOCK.

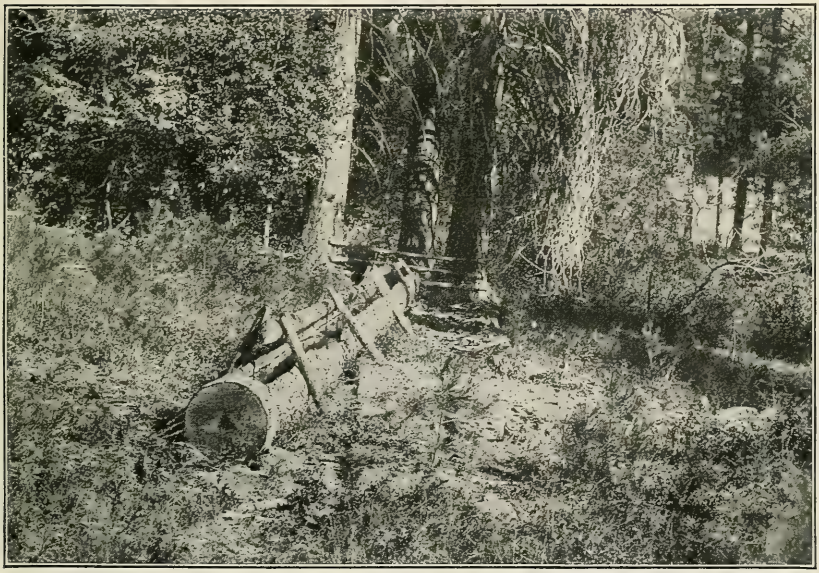
What has been written in these pages on the management of cattle applies primarily to cattle accustomed to running on the open range or in large pastures. The suggestions given will not result in satisfactory management of dry stock or milch cows from dairy herds accustomed to being handled in barns, feed lots, and small level pastures with feed and water convenient; for when such stock are turned loose on a rough mountain range it is difficult to keep them away from the level areas near water. The result is marked local overgrazing and a surplus of feed away on the hills. Where it is advisable, all things considered, to use mountain range for a limited number of this class of stock, extra restrictions in management will be necessary to avoid injury to the range.

COOPERATION.

Cooperation between forest officers administering grazing and the stockmen whose stock use the ranges has been an important factor in the development of range management on the National Forests. It has not always been possible to meet the desires of every individual permittee; but with the support of the majority many changes in the management of both the range and the stock have been made, to the ultimate advantage of Forest administration and the live-stock industry. As a whole, the cooperation thus far has been concerned primarily with underlying principles of regulated use of the range re-

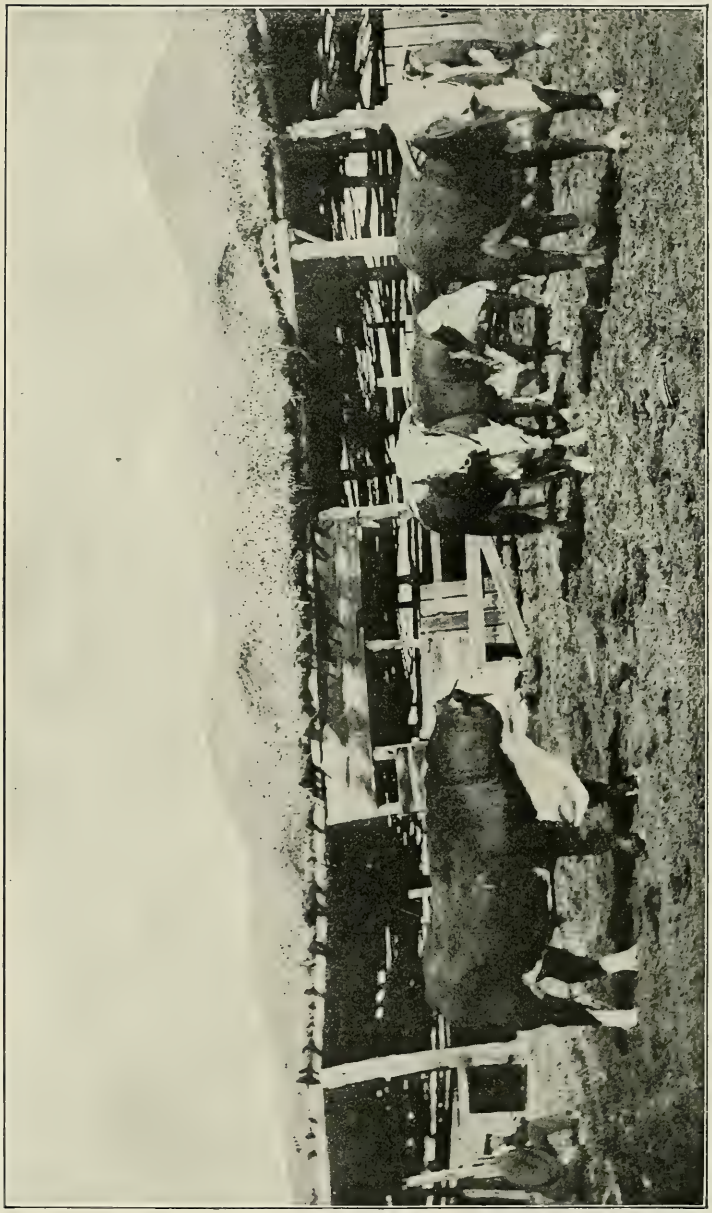
F-10-WRC

Fig. 1.—Springs and seeps which naturally furnish water only in puddles or cow tracks will furnish clean water for a number of cattle if the water supply is developed and troughs installed.



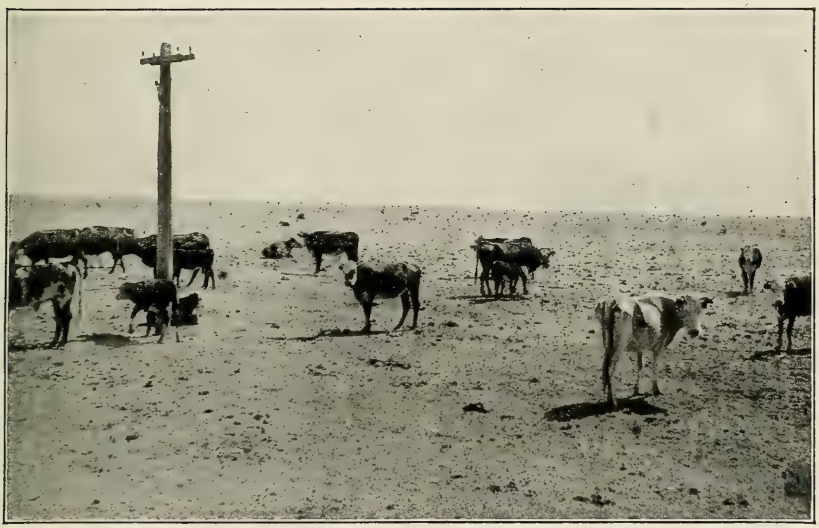
F-11-WRC

Fig. 2.—Springs which are of little or no value in their natural state as watering places for range sheep will furnish water for a band of sheep by a moderate expenditure for developing and fencing the spring and installing troughs.



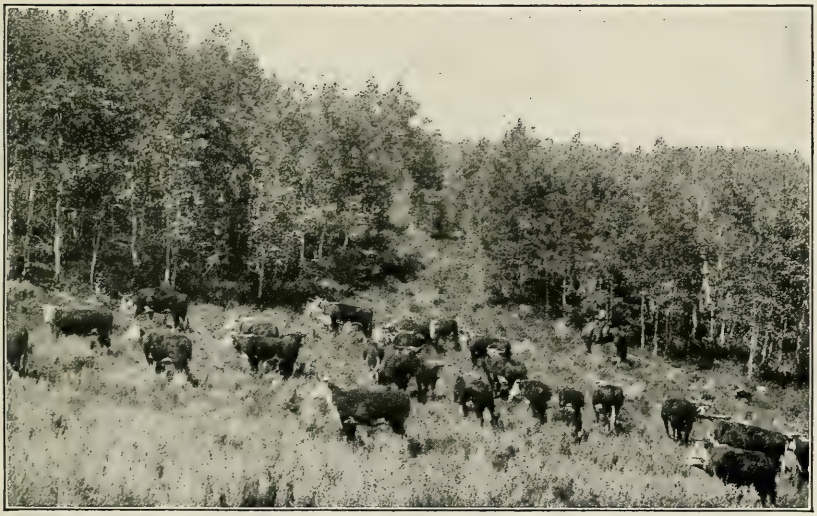
F-24395-A

Pure-bred Hereford bulls purchased for use on National Forest range in Colorado. Cooperation between stockmen using a range unit in common enables the owner of a few cows to secure the services of such bulls as these.



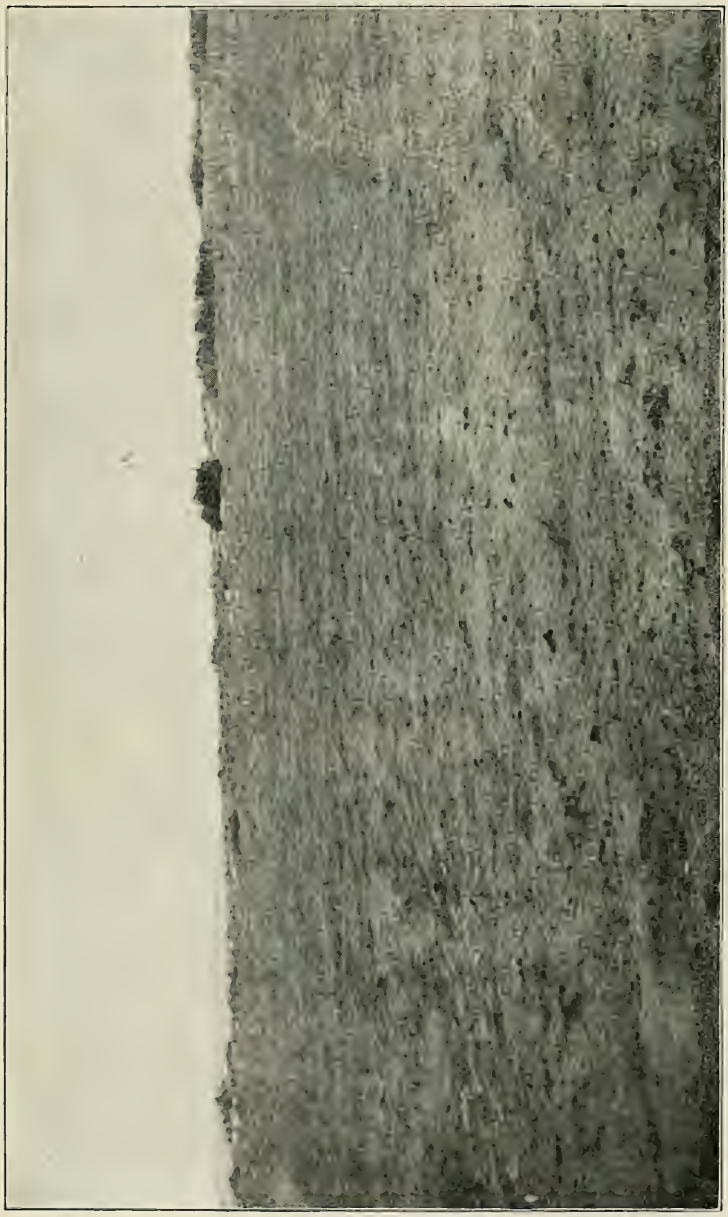
F-35690-A

Fig. 1.—Cooperation is aiding greatly in replacing this class of stock by better animals on the far western ranges.



F-12-WRC

Fig. 2.—The better animals produce more meat than those of lower grade in proportion to the amount of forage consumed, and the greater money returns from the better animals warrant the careful handling of the stock which is so essential to good range management.



F—31439-A

An old sheep bed ground used many nights each year for a number of years under the old system of herding sheep to and from a central camp each day. Very little forage is produced within one-half mile of the center of this bed ground.

sources and with the construction of range improvements. During the last few years, however, organized cooperation has been extended to improvement in the grade of stock and their care and management on the range and to new problems in the improvement of the range. This advancement is the logical result of a need for improved practice to keep pace with increased cost of production and decrease in the supply of range as compared with the demand. The importance of extending cooperation in these matters to all National Forest ranges can not be overestimated. Especially is this true as regards the management of cattle ranges and cattle on the ranges, because of the problems involved, the wide distribution of cattle-grazing privileges, and the necessity of range management by community units. Improvement along these lines, which must come largely as a result of organized cooperation, is of great economic importance in itself, and the development of the kind of cooperation necessary to bring about this improvement will pave the way for improving range practice.

The growing need for united effort, which can come only through the medium of organization on the right basis, is apparent in the change that has taken place in the number of cattle-grazing permittees and in the intensity of grazing. In 1907 approximately 18,500 permits were issued for the grazing of cattle and horses within the National Forests. By 1917 the number had increased to approximately 32,000. The increase in number for 1917 as compared with 1916 was 3,084, showing that the tendency to wider distribution of the grazing privilege is continuing. In 1907 approximately 1,250,000 head of cattle and horses were grazed, and in 1917 over 2,000,000 were grazed, an increase of over 60 per cent in this class of stock. In 1907 the average area per cow or horse was 57.6 acres, and in 1917 it was 43.7 acres.

With this increase in intensity of grazing, number of permittees, and number of stock, the problems to be handled by cooperative effort have increased, and the unit of area for which cooperation should be organized has become smaller. Until a few years ago the most pressing questions could be handled by the National, State, and individual Forest live-stock associations. But to-day the greater number of problems where cooperative effort is important have to do with the improvement and management of the range and the stock within the individual grazing unit. The users of the individual unit of range management have a common interest in all matters pertaining to the management and development of the range and the improvement and management of the cattle and horses within the unit. Proper salting of stock, construction of fences to control the stock, development and maintenance of stock-watering places, proper distribution of stock over the range, reduction in losses of stock on

the range, improvement in grade of stock, and increase in calf crop have a direct effect upon the net profits of the individual user.

More and more attention should be given in the future, therefore, to the organization of the grazing permittees who graze their stock in common on a range unit. It has been shown that such permittees have a common interest in the range practice on the grazing unit, but this alone is not incentive enough, ordinarily, to stimulate organization of local associations and keep them active. There must be a definite worthy purpose to be accomplished in the immediate future by the united effort resulting from the organization, such as the application of a comprehensive salting plan, the eradication of poisonous plants, the construction of drift fences, the use of high-grade bulls, and other similar objects.

With a proper appreciation of the functions and possibilities of live-stock associations in relation to range management on the National Forests, forest officers can do much to encourage organization among the grazing permittees. This can best be done by formulating definite practical plans for the solution of important problems in management of the range unit involved, so that the stockmen will have a definite object in organizing. After a local association has been organized and has been officially recognized by the district forester, special rules may be adopted by the association as needed to carry out specific plans in the management of the range and the stock. Special rules are of two kinds: (1) Those that not only aim directly to promote the interests of stockmen but are designed to secure a better and fuller use of the forage resources; and (2) those that aim wholly to promote the interests of the stockmen.

The following special rules, which have been adopted by various local live-stock associations, will serve to give a clear idea of the nature of these rules and functions:

GROUP 1. AFFECTING DISTRIBUTION OF STOCK AND UTILIZATION OF RANGE.

All permittees grazing cattle and horses on the range within the Caribou Basin allotment will be required to pay their pro rata share of assessments levied by the Caribou Basin Cattlemen's Association for salting, herding, and handling of permitted stock. The advisory board shall purchase salt, attend to its distribution, hire the necessary riders to handle the stock, and levy an assessment sufficient to meet these expenditures.[1]

Subject to the supervision and control of the Forest Service, the Willow Creek Grazing Association is hereby authorized to purchase salt, employ herders or riders, superintend the salting, herding, and handling of all cattle and horses grazed under permit on the range open to this class of stock within the Willow Creek division of district 6 of the Fishlake National Forest. All persons holding permits to graze cattle and horses on this division will be required to cooperate with the association in this respect if they desire to allow their stock

[1] Caribou Basin Cattlemen's Association, Caribou Forest.

to graze at large upon the range, and the issuance of grazing permits will be withheld in all cases and the stock denied admittance to the Forest until the pro rata assessment levied by the association for the above-mentioned purposes during any one year is paid into the treasury of the association. This rule will remain in full force and effect so long as the membership of the association represents a majority of those holding permits to graze cattle and horses on the Willow Creek division of district 6 of the Fishlake Forest.

On or before the final date set for the receipt of grazing applications each year the association will furnish the supervisor with an estimate of the amount of money required for the purposes above mentioned. When permit allotments have been made for the season the supervisor will advise the secretary of the association of the names and addresses of the permittees, the number of stock which each will be allowed to graze upon the Forest, and the per capita assessment which may be levied by the association. This will be determined by dividing the total amount of money to be collected by the grazing allotment of the division. Upon receipt of the assessment the treasurer or secretary of the association will notify the forest supervisor that payment has been made, so that permit may be issued.[1]

GROUP 2. PRIMARILY OF BENEFIT TO STOCKMEN.

1. Beginning with the grazing season of 1917 all permittees authorized to graze cattle on that portion of district 6, Cache National Forest, represented by the Cattle and Horse Growers' Association of district 6, must place on the range with their cattle one registered pure-bred bull of some recognized beef breed for each 25 head of female breeding cattle or fraction thereof, provided permittees grazing less than 25 head of female cattle of breeding age may arrange for joint ownership of bull which shall not represent more than 25 head of breeding cattle: *Provided further*, That in lieu of such bull a permittee may deposit $2.50 per head for each female breeding animal one year of age or over, as his service fee, to be paid into the treasury of the association, the association assuming responsibility of furnishing the necessary bulls to meet such cases.

2. Breeding age of female cattle, as contemplated by Rule 1, will include all female cattle one year old or over.

3. In order to secure more uniform-aged calves no bull shall be turned on the range represented by the association until July 1 of each year.[2]

All permittees of the Montpelier-Elk Valley allotment will be required to furnish one pure-bred bull of beef breed, not less than 15 months of age or more than 8 years, for each 25 head or fraction thereof of female breeding cattle permitted to run on such range. No person shall permit any bull to run on the same range at any other time than during three successive breeding seasons; provided the term "female breeding cattle" shall not apply to female cattle under 12 months of age, and provided that two or more persons may join together in furnishing such bull when the aggregate number of female breeding cattle turned loose upon the same range by any two or more persons does not exceed a number of 25 head.

Any person failing to comply with this rule shall be liable to have his application disapproved the following season. All bulls shall be inspected and passed by a committee appointed by the advisory board of the Caribou Cattlemen's Association.[3]

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[1] Willow Creek Grazers' Association, Fishlake Forest.
[2] Cattle and Horse Growers' Association, district 6, Cache Forest.
[3] Caribou Cattlemen's Association, Caribou Forest.

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MANAGEMENT OF SHEEP ON THE RANGE.

CONTROL.

Control over the number and distribution of stock is a fundamental requirement of effective range management. Control of the number of sheep entering a National Forest or any large range unit of the Forest is comparatively simple. The sheep are under a herder and can be counted in at the Forest boundary and be driven to a range unit in a given time over an established route. On the unfenced sheep ranges of the public domain such control is lacking; and, as a consequence, these ranges are run down and in many places are still deteriorating.

On ranges of the National Forests the problems in sheep management are: (1) To establish range sheep units; (2) to get the sheep on these units with the least damage to the range; (3) to prevent trespass from one range unit to another; and (4) to see that the sheep are so handled as to secure uniform distribution of grazing and full utilization of the forage.

ESTABLISHING SHEEP RANGE UNITS.

In general, the practice on ranges within the National Forests has been to divide the sheep range into units which will furnish sufficient forage for a band of sheep during the established grazing period. In some cases the range unit, or allotment, includes range for several bands of sheep owned by one permittee.

The assignment of an individual range to each band places responsibility for proper use of the range squarely upon the individuals

owning and those herding the sheep. This is desirable for the sheep owners and for the range. It does away with the old practice of racing for a desirable range area, trampling down forage, and doing permanent injury to the range en route; and, if trespass from one unit to another is prevented, it makes possible the use of the poorer areas of range when they can be used best, without danger of other bands coming in the meantime and grazing off choice areas. The advantages of range sheep units to accommodate one band of sheep, therefore, are so marked that an effort should be made to assign each band to a definite range unit whether two or more bands are owned by one permittee or not, for competition between herders under one employer may sometimes result in unnecessary abuse of the range.

CONTROL BY UNITS.

To secure the best results trespass between units must be avoided, for the individual using a range unit may hesitate to graze properly the range allotted to his band if by doing so he defers grazing upon a choice piece of range which will be a temptation to an adjoining band. Further, trespass upon an allotment might result in overgrazing of the allotment before the close of the season.

Innocent trespass may occur unless the boundaries of units are readily recognized on the ground. For this reason the unit boundaries should be along prominent ridges, so far as is practicable. Streams sometimes are made the dividing line, but where it is possible a band should be allowed the range on both sides of a stream which sheep will cross readily. Otherwise sheep of two bands may mix or there may be too many sheep watering at one stream for the welfare of the range.

Unfortunately, the range within the boundary lines which form a natural range unit frequently furnishes too much or too little forage for the sheep in one band. On rugged mountain range it is usually possible to adjust the boundary lines so as to exclude or include range for probably 200 or more sheep and still have boundary lines which should make innocent trespass unlikely. Where the estimated grazing capacity of the unit is greater or less than the number of sheep in the band by, say, from 50 to 200 head, the difference is so small that it is not always possible to enlarge or reduce the allotment to accommodate the size of the band and still have satisfactory boundary lines. Where this is the case the size of the band should be adjusted eventually to fit the range.

As far as practicable, the size of the unit or allotment should be adapted to the number of sheep in the band; but this principle should not be followed if waste of forage, overgrazing, or innocent trespass, due to poor boundary lines, will result. From 1,000 to 1,200 ewes

with their lambs, as a general rule, should be the most run in one band. Only in exceptional cases should the band exceed 1,500 ewes with their lambs, or from 2,000 to 2,500 dry sheep. Larger bands are difficult to handle without injury to a forest range.

HANDLING THE SHEEP.

An exhaustive discussion of handling sheep on the range would itself fill a volume. The aim here is simply to point out the more important features of proper handling without attempting to explain fully the ways in which the general procedure recommended should be adjusted to the local conditions of range and personnel.

HERDING.

As early as 1909[1] investigations showed that mountain summer range grazed by sheep under fence supported from 25 to 50 per cent more sheep than were being grazed on the same acreage of similar range on which the sheep were herded by the methods generally practiced at that time, and that the pastured sheep made better gains in weight than the herded sheep. It was found also that there may be a variation of at least 25 per cent in the grazing capacity of a given range when used by the same sheep under different herders. From four years' study of the actions of the pastured sheep and the methods of herding on unfenced range it was concluded that the marked differences in grazing capacity and in growth of the sheep under the two systems were due largely to a few differences in the way the sheep were handled—differences which could be largely eliminated by improved methods of herding.

The desired changes have been tried out in many experiments, and perhaps 50 per cent or more of the sheep grazed on ranges within the National Forests are now herded under improved methods. The problem now is to secure the adoption of better methods by the other 50 per cent.

One of the first steps in bringing this about is to follow strictly the regulation[2] below:

> Sheep and goats must not be bedded more than three nights in succession in the same place, except when bedding bands of ewes during the lambing season; and must not be bedded within 300 yards of any running stream or living spring, except in rare cases where this restriction is clearly impracticable.

The three-night limit is for rare cases where one-night bedding in a place is clearly impracticable. As a general rule sheep should be bedded one night in a place. The damage to range so characteristic around old bedding grounds will then be eliminated, and the

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[1] James T. Jardine. The Pasturage System for Handling Range Sheep. U. S. Forest Service, Circular 178, 1910.

[2] U. S. Forest Service. The National Forest Manual, Grazing Regulation 26.

sheep will be on fresh feed during the cool hours of the morning and evening, when they graze best on the summer range.

The herder should be with his sheep, ordinarily, from the time they begin grazing in the afternoon until they are shaded up the following forenoon. This is necessary to prevent straying and as a protection against predatory animals. Coyotes, especially, attack sheep most frequently in the late evening and early in the morning. Bears usually attack the band during the night. In some localities the herder remains with his sheep all the time, carrying his camp outfit, provisions, and, if necessary, drinking water, on a pack animal, usually a burro. This practice is desirable in all localities; but where feed is good and the range untimbered, or only partly timbered and not too brushy, good results are obtained where the herder leaves the sheep for a short period during the middle of the day, while they are resting. This matter, therefore, should be adjusted to the local conditions of range and the class of herders.

The sheep should be allowed to begin grazing soon after daybreak so that they will fill up before the heat of day. Their course of travel can be directed by the herder, and, if necessary, the leaders should be checked so that the herd will spread out quietly over an area sufficient to provide forage for the morning. Until the sheep settle down to rest after the morning grazing the herder should move quietly around the outside of the herd, keeping track especially of the leaders, but not disturbing them except where necessary to check them or change their direction.

Between 7 and 9 o'clock in the morning during summer the sheep usually settle down to rest. They will not move far during the remainder of the warm part of the day and need not be disturbed. The herder should go around the outside of the band occasionally to see that none of the sheep are straying off.

During the time that the sheep are resting the herder has several hours to do his main cooking for the day. Where the burro system is followed he usually makes a cup of coffee before starting his sheep at daybreak. When the sheep shade up he unpacks his burro and does his cooking. Herders who do not remain with the sheep all the time, carrying their provisions and cooking outfit, return to the herder's supply camp while the sheep are resting and do their cooking and camp work for the day. Herders who follow this plan usually eat two meals at the supply camp each day, one upon arrival in the morning and one before leaving to round up the sheep and remain permanently with them during the night. The herder's supply camp should be moved often enough so that he will be able to go around the band occasionally while they are resting. During the scouting trips around the band a bedding place for the night should be selected; and, if the burro system is not being followed, the

herder's bed and salt for the sheep should be moved to the new location. A site comparatively open, free from down timber and brush, and larger than the actual bedding space required should be selected. On an open site the lambs can find their mothers with the least difficulty; there is least danger from attack by predatory animals, and there is less danger of a "pile up" or crippling of sheep in case the band is frightened during the night.

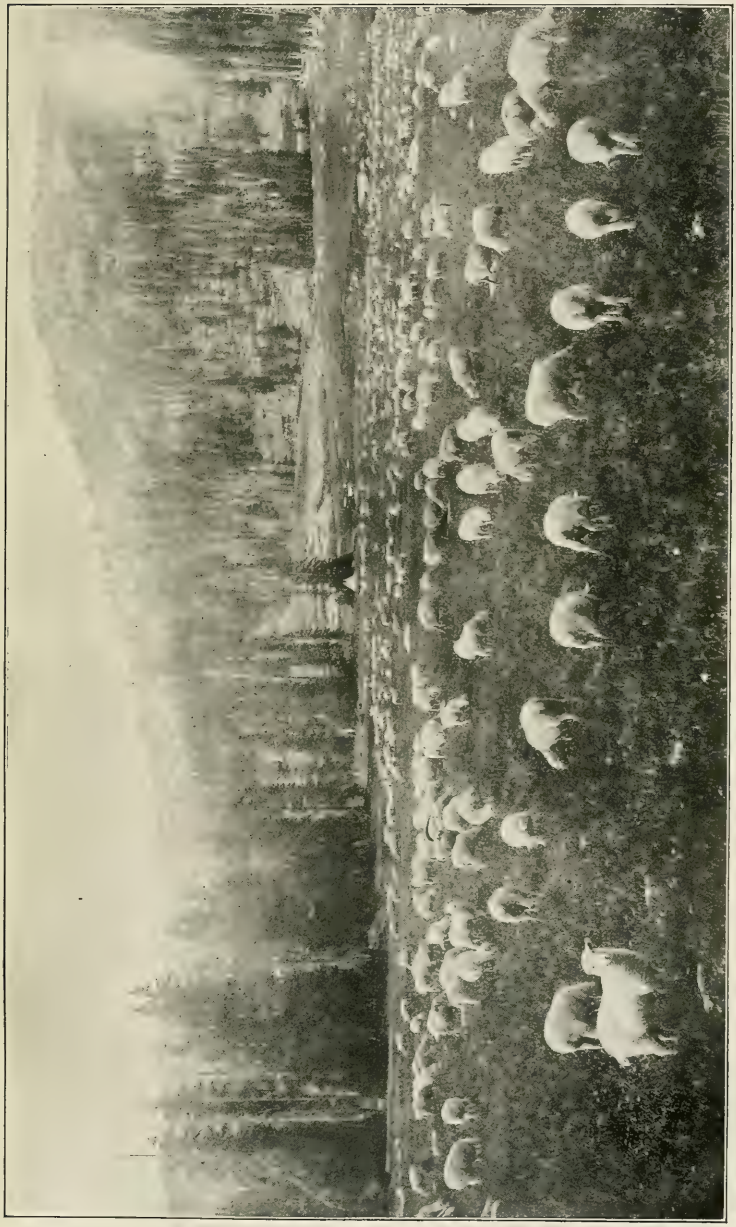
High, dry ground on mounds or ridges furnishes the best sites for bedding grounds. Sheep bedded in canyons with adjacent intermediate ground open or comparatively free from dense timber and brush have a tendency to leave the bed ground and drift to the ridges. They rarely drift far from a ridge into a canyon.

Where heavy timber and brush extend over large areas of the range, small openings are of vital importance. Their location should be known, and grazing should be planned so as to use them to best advantage.

In gathering the sheep in the evening it is especially important that the herder circle the outermost tracks made by the sheep during the day. Tracks are the best indicators of where the sheep have been. From this outer circle the sheep should be turned toward the site selected for bedding. Stragglers and isolated bunches should be driven to the main band. By about 6 o'clock the sheep should be collected into a loose band near the bedding ground. They may then graze in this formation until they bed for the night. Meantime, the herder should move about them, counting the bells and markers and watching the ewes and lambs. Lambs that can not find their mothers or ewes that can not find their lambs in a reasonable time may be indications that the sheep are not all in. Care in rounding up the sheep at night can not be overemphasized. The greatest losses occur from leaving small bunches away from the band, subject to attack by predatory animals.

WATERING.

The length of time sheep may be away from water depends upon the character of the forage and the weather. On high mountain summer range within National Forests sheep have been grazed successfully during the entire summer without water. Ordinarily, when the vegetation is succulent, the weather cool, and heavy dew frequent, sheep do not require water oftener than every three or four days. During hot, dry days they will do best if shade, forage, and water are convenient. Areas of succulent feed near water and shade should be reserved for this period. In late summer and fall cool weather and storms ordinarily make watering oftener than every three or four days unnecessary.



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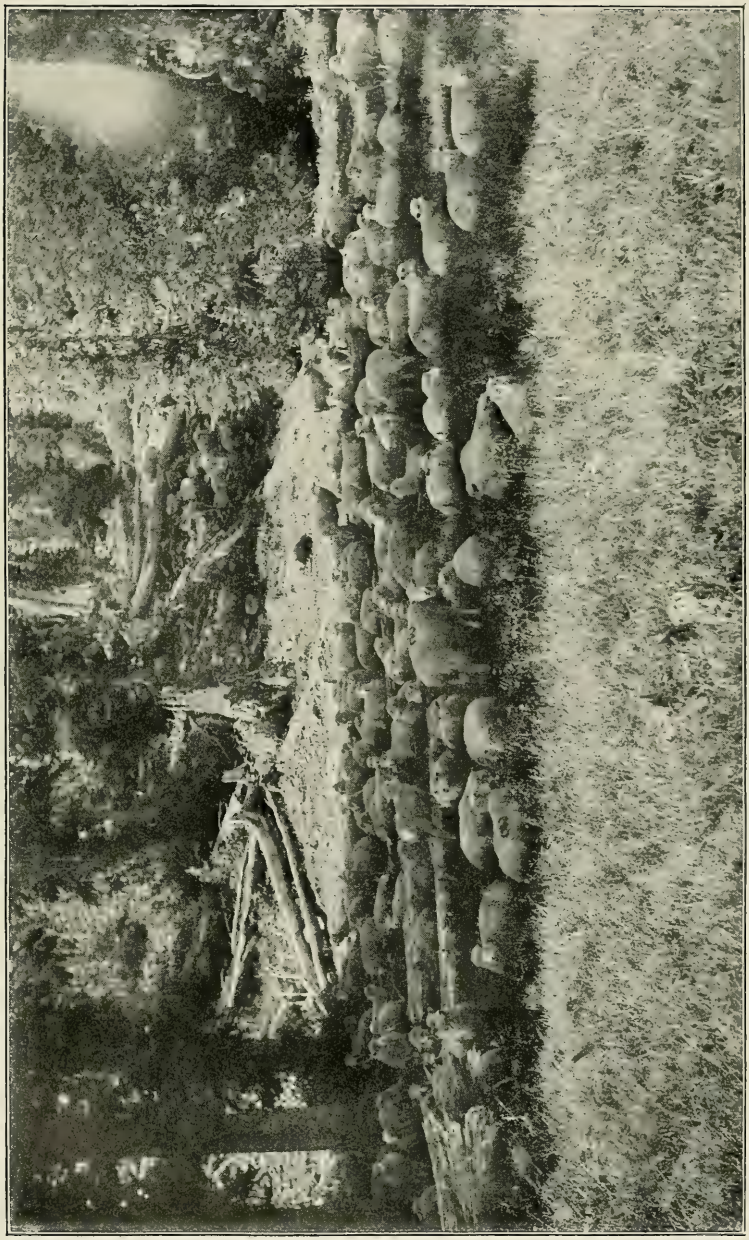
Sheep collected for the night near the herder's tepee. With these sheep handled under the bedding-out system a new bed ground was used each night. The sheep had fresh feed in early morning and late evening and there was little injury to the range.



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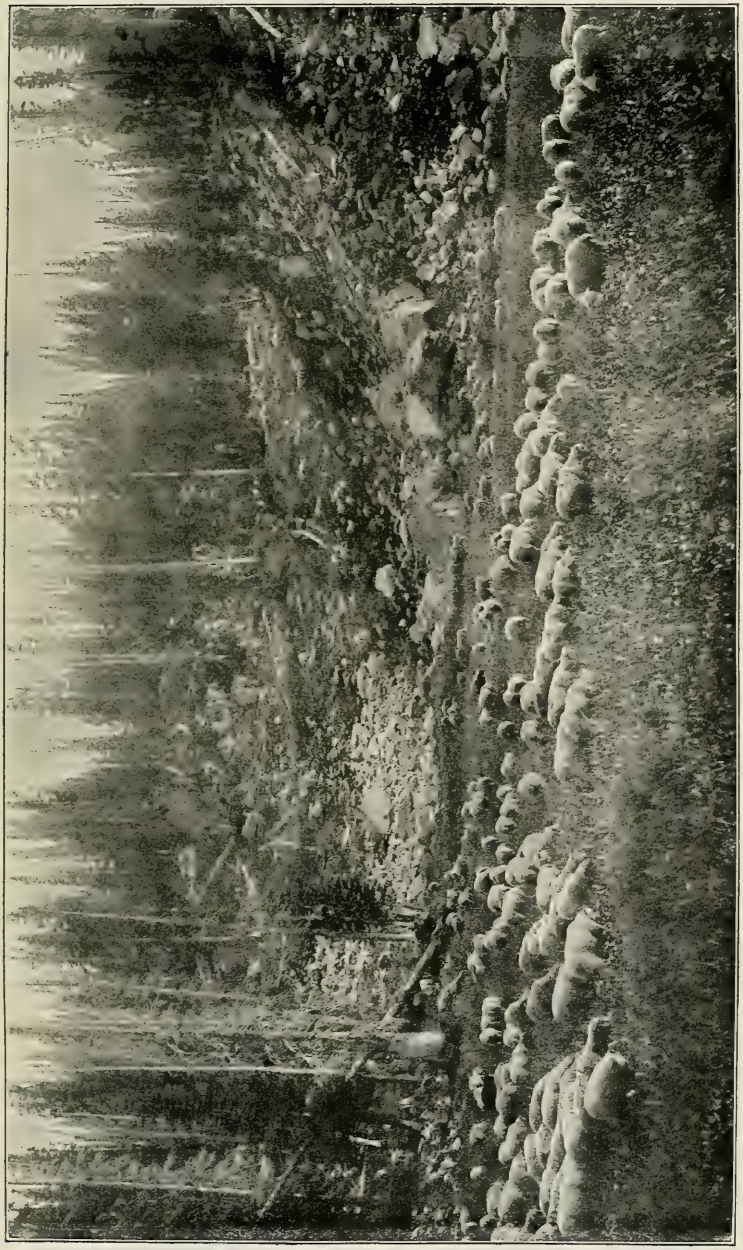
Sheep "shaded up" at 9 a. m. under the bedding-out system of herding.



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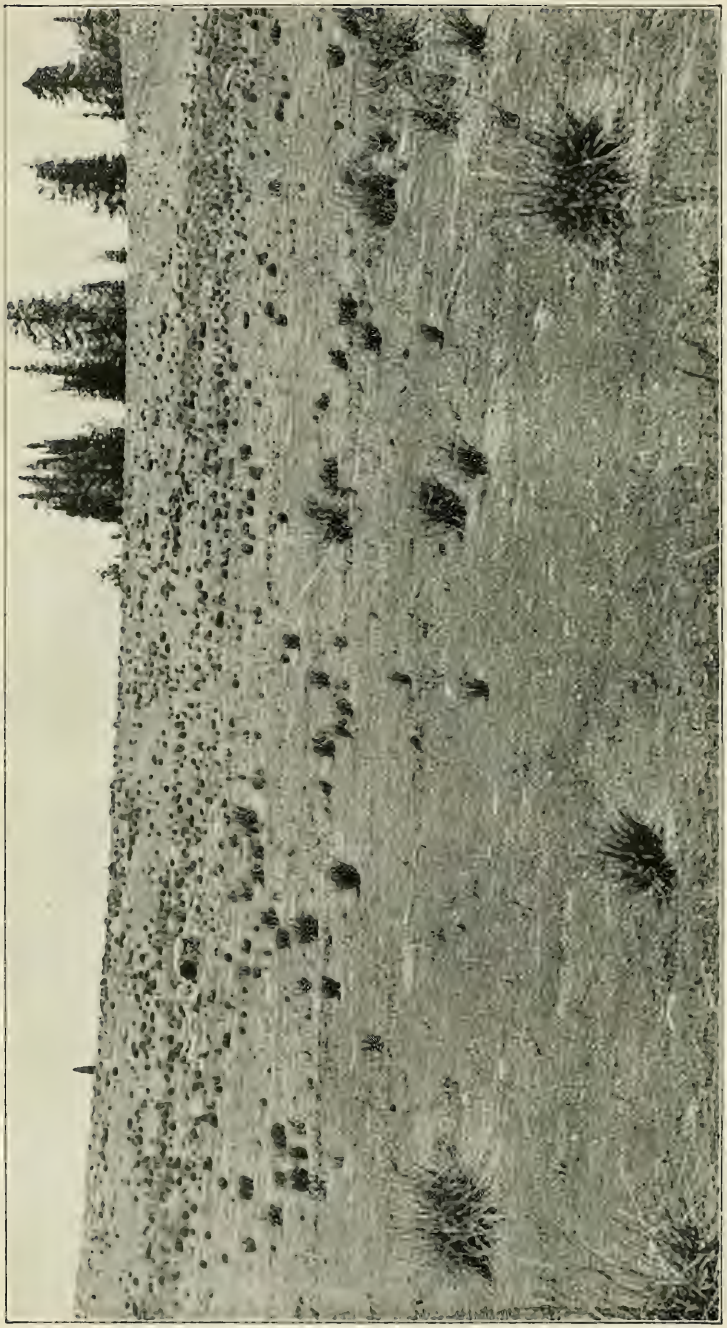
Sheep handled under the bedding-out system grazing quietly on good feed just before sundown.



Range heavily overgrazed by sheep prior to 1916, but protected against grazing during 1916, 1917, and 1918. The large number of small plants are 1 and 2 year old plants of mountain bunch grass.

If the sheep are herded as suggested in the preceding paragraphs, watering oftener than every few days is not only unnecessary but may not be for the best interests of the sheep if they can reach water only by traveling several miles into deep canyons. They should be grazed, not driven to water, and then grazed back. Careful planning will make it possible ordinarily to direct the course of the band so that they will reach water in late morning or midafternoon. An hour on water during these periods of the day will be sufficient. They should not be shaded up near the water for several hours. Such practice is equivalent to bedding near a stream or living spring and may result in unnecessary contamination of the water supply.

SALTING.

Salt is essential to the welfare of the sheep and makes them more contented and easier to herd. It would be best to have salt on the bedding place every night, but this is not always practicable on the range without a great deal of labor. Sheep can be salted, however, at least every five to seven days.

Crystal sack salt or dairy salt should be used. About 100 pounds every five days for 1,200 ewes and their lambs should be a minimum. Where practicable, from 50 to 75 pounds of salt every three days for a band of 1,200 ewes is more satisfactory than a greater amount fed less often. Salting every night on a new bedding ground helps to make the sheep contented during the night.

The salt is sometimes fed in portable wooden or canvas troughs. The necessity of having a great many troughs or of moving them frequently affords a temptation to bed the sheep more than one night in a place. Furthermore, if sheep are going to the salt troughs at all times of the night the disturbance may make the band restless. The salt should be distributed, one or two handfuls in a place, on rocks, clean ground, or grass. Care should be exercised not to put it where there is gravel, sand, or loose dirt. Sand or gravel in the salt may result in marked injury to the teeth. If salt is distributed in small piles before the sheep reach the salting ground, there will be comparatively little waste and all the sheep will get salt in a short time. It is doubtful if this method will be replaced to any great extent by salting in troughs if the sheep are bedded a maximum of three nights in one place.

TIMELY USE OF FORAGE.

A well-thought-out plan for grazing the range allotted to each band of sheep on summer range will be to the advantage of both sheep and range. Usually on each allotment there are areas where the forage grows to maturity quickly and then dies. On other areas the forage becomes tough and of low palatability by midseason. On

still others the forage remains green and tender throughout the season. Sheep, especially ewes and lambs, make most rapid gains on succulent tender forage. For this reason the weight of lambs at the close of the grazing season may be varied at least 5 pounds by a difference in the plan of grazing the range allotted to the band. The endeavor should be to use the range so as to have green, tender feed for the longest time possible. This will necessitate moving the herder's supply camp, if one is used, oftener than is done ordinarily, but the extra moving will be justified by the production of heavier sheep. Range with green feed and shade should be reserved for use during the hot weather.

The owner of the sheep, or some one employed by him, should see to it that the herder is kept supplied with provisions and salt for the sheep and that the herder's camp is moved as often as is necessary to keep it near the sheep, provided the burro system is not followed. Lack of consideration for the herder in these matters usually results in neglect of the sheep or injury to the range from driving the sheep to the supply camp and holding them too long on near-by range. The practice which allows the owner of the sheep or the camp mover to visit the herder at intervals of two weeks or longer is out of date, or should be, in all localities. Whoever does this work might profitably spend more time on the range helping to work out the order of camps, seeing that a prompt search is made for lost sheep and that due consideration is given to the needs of the herder, so that he can devote his attention entirely to proper handling of the sheep.

The method of handling sheep here outlined is now followed, with slight variation, in the management of perhaps 50 per cent of the 8,500,000 sheep grazed within the National Forests and should be followed by the other 50 per cent. The manner in which the sheep are handled is an important factor in deciding whether certain watersheds and forest areas may be used for sheep grazing without unwarranted interference with watershed protection and forest protection, and is important in determining the grazing capacity of the range as well as the gain in weight of the sheep.

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STOCK DRIVEWAYS.

During the fiscal year ended June 30, 1917, a total of 2,176 permits were issued, allowing 56,954 head of cattle, 1,148 head of horses, 3,385,429 sheep, and 47,897 goats to cross National Forest lands en route to and from the ranges used by the respective permittees. The number of stock which uses the National Forest lands in this capacity varies little from year to year. There may be a slight decrease in the future, but it will be necessary to provide crossing privileges for at least 3,000,000 head of stock each year for a number of years, and for nearly this number permanently. The distances that the stock are driven vary from perhaps less than 1 mile to about 125 miles. It is evident, therefore, that a considerable acreage must be devoted to this phase of range utilization. It is equally evident that on every National Forest where grazing is an important activity a great deal of attention should be given to getting the stock to their allotted range with the least injury to timber growth, watersheds, and the range, and with the minimum interference with proper grazing use of range along the way.

Driveways have been established over portions of the National Forests where it is necessary for stock to cross regularly. Many of these driveways have been in use for a number of years and show the ill effects of premature grazing, overgrazing, and trampling. Hill,[2] for example, reported on this subject as follows:

> One of the most serious menaces to reproduction (western yellow pine), as well as to range, occurs on stock driveways. Even at best an excessive number

[1] A few reprints available in the Forest Service, Washington, D. C.
[2] Hill, Robert R. Effects of Grazing upon Western Yellow Pine Reproduction in the National Forests of Arizona and New Mexico. U. S. Dept. of Agriculture, Bul. 580, 1917.

of stock must use these strips of range, and injury can not be avoided. However, all practicable means should be used to conserve the stand of forage by furnishing sufficient feed for the stock using the driveways to reduce the injury to reproduction to a minimum. In order to accomplish this, it is recommended that driveways be used as little as possible; that, whenever practicable, they be closed to grazing except by passing stock; that a sufficient number be established to prevent overgrazing; and that water be furnished in abundance at proper intervals along them.

These conclusions and recommendations are sound, and should be considered seriously in the location and use of stock driveways. It might also be well to consider the possibility of increasing the number of driveways and adopting a system of rotation in their use, so as to give each driveway protection against grazing during the growing season for, say, two years in succession out of each four-year period. In some cases it may be possible and necessary to narrow the driveway to the width actually necessary to drive a band of sheep over and to provide supplemental grazing areas at intervals along the way where the sheep can be furnished the amount of grazing necessary for their maintenance en route. Should this be done, the distance between grazing areas and the amount of grazing required for each band at each stop should be determined with care, so as to prevent overgrazing as well as unnecessary consumption of forage en route. The grazing areas might be numbered and a plan developed whereby the first half of the stock to pass over the driveway would use only a designated number of grazing areas, leaving the rest fresh for later stock.

It should be understood that these are only suggestions for consideration in adjusting any given driveway problem. No definite policy can be offered at this time. Careful study of the problem on every important grazing Forest is urged. The cumulative annual damage by this time may have reached a stage where a change in a driveway or a portion of it is imperative. A driveway should not be looked upon as a thing fixed for all time, and therefore of no further concern. Each driveway should be inspected annually to determine the condition of the range, the damage to timber growth, the extent of erosion, if any, and possible changes to minimize damage and facilitate movement of stock to and from the range.

RANGE RESEEDING.

SEEDING TO CULTIVATED FORAGE PLANTS.

The grazing capacity of western range lands varies from small meadows where a few acres will support a cow during the summer grazing season to lands where 100 acres will barely support a cow throughout the year. Between these extremes there are all grades of range, with the greater part somewhere near the average of 2

or 3 acres per cow per month, waste areas excluded. The main reasons for this low grazing capacity, as compared with the capacity of most farm pastures, are (1) the natural low productivity of the range lands and (2) the range deterioration.

Whatever the cause of low grazing capacity, it is only natural that there should be many appeals to National, State, and private agencies for seed of forage plants which will work wonders in the way of increasing the supply of forage and improving its quality. Such plants may be found or may be developed at some time in the distant future; they are not available at present.

There are, however, limited areas within the National Forests upon which the expense of seeding to cultivated forage plants may be warranted by the resulting improvement in the forage crop. Over 500 seeding tests have been conducted by the Forest Service since 1907 in an attempt to determine just what kind of lands can be seeded profitably, the species to use, and the methods which will secure the best results. The information available is largely included in Department of Agriculture Bulletin 4.[1]

The results presented in Bulletin 4, as well as the results of investigations since it was issued, indicate that the expense of seeding range lands to cultivated species is warranted only on mountain meadows and other areas of minor extent 500 feet or more below true timber line and having favorable soil and moisture conditions. Even on lands of this character, if they already support a stand of native perennial vegetation covering 60 per cent or more of the ground surface, seeding to cultivated forage plants will rarely be successful. The soil is in poor condition to receive the seed, and the cultivated forage plants will rarely replace the hardy native vegetation. It is realized that this description will not enable the reader to decide readily whether a given area should be seeded; but the limitations given will exclude at once dry bunchgrass hillsides, dry timbered or untimbered lands where there is a scanty growth of native grasses, weeds, or shrubs, and other areas where the native vegetation indicates that soil and moisture conditions are unsuitable for all but hardy, drought-resistant native plants.

Most men having to do with the supervision and use of western range are somewhat familiar with the conditions under which timothy, redtop, and the clovers can be grown successfully on farms and ranches. If similar conditions of soil and moisture are found on range lands, and the native vegetation is scant, the advisability of seeding to cultivated plants should be looked into. Not infrequently, however, recommendations for seeding to cultivated forage plants are based upon the fact that timothy, redtop, bluegrass, clover, or

[1] Sampson, Arthur W., The Reseeding of Depleted Grazing Lands to Cultivated Forage Plants, U. S. Department of Agriculture, Bul. 4, 1913.

some other cultivated species is found growing along wagon tracks, in the center of a wagon road, or around camp grounds. In such places the ground usually has been made more favorable for receiving the seed and retaining moisture as a result of some disturbance or fertilization. Further, it is probable that a great many seeds have been scattered in these places compared with the few which grow and become established. The conditions of soil, moisture, fertility, and competition of native vegetation where the cultivated plants are found growing as compared with those on the area to be seeded should be carefully studied before recommendations are made.

It should be remembered that seeding to cultivated forage plants will cost[1] from $1 to $5 per acre if properly done, and that protection against grazing during the first year after seeding is essential to success. Cultivated species can not be expected to succeed and continue productive on the range with less protection than is required for their successful growth on the farm.

It is not the object of this discussion, however, to discourage all consideration of seeding to cultivated forage plants. On the contrary, this phase of range improvement must be given more consideration as grazing becomes more intensive and as the value of range increases. What is needed is more careful examination of the comparatively small acreage of lands where soil and moisture conditions are similar to those of farm and ranch lands which are producing profitable pasturage of cultivated forage plants. Of lands in this class the most promising are mountain meadows and parks, alluvial flats along streams, and other areas of deep soil with considerable organic matter.

There undoubtedly are many acres of mountain meadow and park lands within the National Forests which should be improved by seeding and by other means as soon as it is feasible to follow seeding by the care and grazing management necessary for successful growth and maintenance of the forage crop resulting from seeding. These areas in most cases are such as for many years have been favorite congregating places for cattle, bedding grounds for sheep, salting grounds for both classes of stock, locations for separating corrals, round-up grounds, and camp grounds. In a great many cases excessive use for these purposes has hastened erosion and lowered the stream bed until the water level is far below the surface of the ground; and the meadow, once moist and productive, has become dry and low in productivity. Seeding alone will not bring about the desired improvement in such cases. The water must be distributed over the surface instead of running down a channel 5 to 20 feet deep, and abusive use must be eliminated. The fact that many mountain

[1] Sampson, Arthur W., The Reseeding of Depleted Grazing Lands to Cultivated Forage Plants, U. S. Department of Agriculture, Bul. 4, 1913.

meadows in run-down condition are privately owned is evidence that the demand for range has not become acute enough to result in expensive improvement and the effort necessary for preservation and wise use. To some extent this applies also to seeding other than in meadows. When everybody concerned is prepared to share voluntarily in the improvement and upkeep and wise use of all range, the matter of seeding will assume greater importance than at present in comparison with other range improvements.

Meantime there is opportunity for careful observation on every National Forest to select the areas where seeding will probably be warranted when this method of improvement becomes of enough comparative importance.

Time of seeding, quantity of seed, methods of seeding, cultural treatment, and protection from grazing until the plants have become firmly established are fully discussed in Bulletin 4.[1] The selection of species for seeding also is fully discussed in the same bulletin. The list given, however, includes a number of species which should be tested further by seeding under expert supervision before they are used extensively. The species which have given the best results are timothy, Kentucky blue grass, smooth brome grass, redtop, alsike clover, and white clover. Range seeding should be confined primarily to these species unless other species are known locally to have given satisfactory results under conditions similar to those on lands where seeding is to be done.

Investigations have been under way for several years to determine the practicability of hastening revegetation on depleted ranges by seeding with seed of suitable native forage plants. A number of promising species have been grown in nurseries in the hope of selecting plants which can be placed under cultivation so that seed may be secured without prohibitive cost. The indications are that, for a number of years at least, the most economical method will be to protect areas where the plants of which seed is desired are already growing vigorously and from these areas collect seed for use on similar denuded lands in the same locality. While the cost of collecting the native seed is high and the seed often of low fertility, there appear to be future possibilities of building up and maintaining range in this way. Further tests on a large scale are under way to find out more definitely the results which may be expected, as well as the cost. Reliable data will no doubt be available by the time that extensive seeding can be undertaken.

NATURAL RESEEDING.

The limited possibility of increasing the forage crop by seeding range lands to cultivated forage plants emphasizes the need of build-

[1] Sampson, Arthur W., The Reseeding of Depleted Grazing Lands to Cultivated Forage Plants. U. S. Department of Agriculture, Bul. 4, 1913.

ing up depleted ranges and maintaining all range lands by giving the desirable native forage plants a chance to reproduce. The maintenance of maximum forage production would not be difficult if grazing could be deferred on all ranges each year until the forage plants have gone to seed. Protection to this extent, however, is clearly impracticable because of the need for range forage during the main growing season of the vegetation. Necessity, therefore, demands a system which will permit the maximum grazing possible during the growing season and still maintain the range. Such a system must take into consideration the requirements of the vegetation which makes up the forage crop and the relation of grazing to these requirements at different stages of growth. For many of the more important forage plants the natural requirements of growth and reproduction, as well as the way in which grazing interferes with or promotes these requirements, have been studied; and though there is a great deal yet to be learned along these lines, fundamental principles of grazing management have been developed which have given good results in practical application.

It remains to extend the application of these principles to other ranges. In doing so, the first step is to fix the opening of the grazing season in accordance with the suggestions of the paragraphs on Grazing Periods. Unless this is done, the management which follows will not produce the results desired. The next step is to carry out the suggestions given in the discussion of Grazing Capacity. It is important, then, that the management of the stock be such as to secure as nearly as possible uniform grazing over the range. Local overgrazing around watering places, bedding grounds, salting grounds, and other places where stock naturally congregate must be prevented; where it can not be prevented, it should be limited to small areas. Otherwise, the damage from this source will offset, or more than offset, the improvement from other measures. These steps must precede or accompany the application of a system of deferred and rotation grazing intended to promote natural reseeding.

DEFERRED AND ROTATION GRAZING.

The following are some of the principles developed in investigations on the relation of grazing to growth and reproduction of range forage plants.[1]

(1) Removal of the herbage year after year during the early part of the growing season weakens the plants, delays the resumption of growth, advances the time of maturity, and decreases the seed production and the fertility of the seed.

[1] Sampson, Arthur W., Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation. U. S. Department of Agriculture, Journal of Agricultural Research, Vol. III, No. 2, pp. 93–147, Nov. 16, 1914.

(2) Under the practice of yearlong or season-long grazing, the growth of the plants and seed production are seriously interfered with. A range so used, when stocked to its full capacity, finally becomes denuded.

(3) Grazing after seed maturity in no way interferes with flower-stalk production. As much fertile seed is produced as where the vegetation is protected from grazing during the whole of the year.

(4) Deferred grazing (grazing after seed maturity) insures the planting of the seed crop and the permanent establishment of seedling plants without sacrificing the season's forage or establishing a fire hazard.

(5) Deferred grazing can be applied wherever the vegetation remains palatable after seed maturity and produces a seed crop, provided ample water facilities for stock exist or may be developed.

(6) Yearlong protection against grazing of the range favors plant growth and seed production, but does not insure the planting of the seed. Moreover, it is impracticable, because of the entire loss of the forage crop and the fire danger resulting from the accumulation of inflammable material.

Excessive damage from grazing during the early part of the growing period is largely avoided if grazing does not begin until the main forage grasses are in the boot. But between this opening date and the time of seed maturity of these same plants there is a period of about six weeks, during which continuous grazing year after year on a fully stocked range would materially weaken the forage plants and result in range deterioration. The system of deferred and rotation grazing aims to minimize the injury from grazing during this period (1) by having each portion of the range bear its share of the early grazing and (2) by protecting each portion of the range in its turn until after seed maturity, so that the main forage plants will regain their vigor and reproduce either from seed or vegetatively.

Suppose, for example, that the grazing season on a range unit or range allotment covers the period from May 1 to October 31 and that the vegetation is similar in character and the period of growth about the same throughout the unit, with the seed of the main forage plants maturing September 1. To apply a deferred and rotation grazing system, the unit might be divided into three parts of about equal grazing capacity, in a way to give the best distribution of water and shade and the best control of stock on each third.

Suppose the third most in need of improvement is numbered 1, the one second in need of improvement numbered 2, and the third division numbered 3. The order of deferred grazing for a period of six years should then be as follows:

Year.	Area No. 1.	Area No. 2.	Area No. 3
1919	Sept. 1 to Oct. 31	July 1 to Aug. 31	May 1 to June 30.
1920	do	May 1 to June 30	July 1 to Aug. 31.
1921	July 1 to Aug. 31	Sept. 1 to Oct. 31	May 1 to June 30.
1922	May 1 to June 30	do	July 1 to Aug. 31.
1923	do	July 1 to Aug. 31	Sept. 1 to Oct. 31.
1924	July 1 to Aug. 31	May 1 to June 30	Do.
1925 to 1930 [1]			

[1] Repeat order of grazing for 1919 to 1924.

The foregoing example applies to range where the soil still retains most of its original fertility and where there is still considerable of the original perennial vegetation. If the range has deteriorated beyond this stage, more than two years of deferred grazing on each third of the range will be necessary for revegetation, and the rotation will extend over a longer period. The number of years necessary or the number advisable depends upon the extent to which the vegetation has been killed out and the soil depleted in fertility[1] and must be decided in the individual case after a careful examination of the vegetation. Deferred grazing should be continued until there is satisfactory reproduction of the principal forage species.

Of course, there are difficulties to overcome in the application of deferred and rotation grazing, but in only a very few cases is it impossible to work out and eventually apply a plan which will aid in maintaining the vigor and productiveness of the main forage plants and occasionally allow the production of a seed crop. On ranges within the National Forests the two main difficulties are: (1) Great variation in character of forage and growing season, due to variation in altitude and exposure; (2) lack of fences or other means of controlling the stock, especially cattle.

The division of range into spring grazing extending up to about July 1 and summer grazing from July 1 on, as suggested in the discussion of seasonal grazing, will in part overcome the difficulty of variation in growing season. The growing season throughout the range set aside for spring grazing will ordinarily be uniform enough to admit of a plan for deferred grazing to meet the needs of this range. Likewise, the growing season on the range opened to use about July 1 will be sufficiently uniform to make possible a subdivision for deferred grazing along the lines of the sample plan given. This division into spring and summer grazing has been made on parts of the range on many National Forests, especially on the sheep range. And in many instances deferred and rotation grazing has been applied in the way shown in figure 4. Eventually there must be some such division on most of the cattle ranges, with corresponding control of the cattle to prevent premature grazing of the higher range in certain cases and in others to prevent seasonlong grazing and overstocking of the range at the lower altitudes.

The variation in season of growth between the Forest boundary and the mountain top and high basins is so great that inclusion of the

[1] Sampson, Arthur W., Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation. U. S. Dept. of Agriculture, Journal Agricultural Research, Vol. III, No. 2, pp. 93–147, Nov. 16, 1914.

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Sampson, Arthur W., Plant Succession in Relation to Range Management. U. S. Dept. of Agriculture, Bul. 791, 1919.

whole stretch of country in one grazing period without control of stock between the boundary and the sky line is ineffective. There should be a division to provide units of management upon which grazing conditions are nearly uniform. Identical or even approximately identical conditions can not be expected, because the low

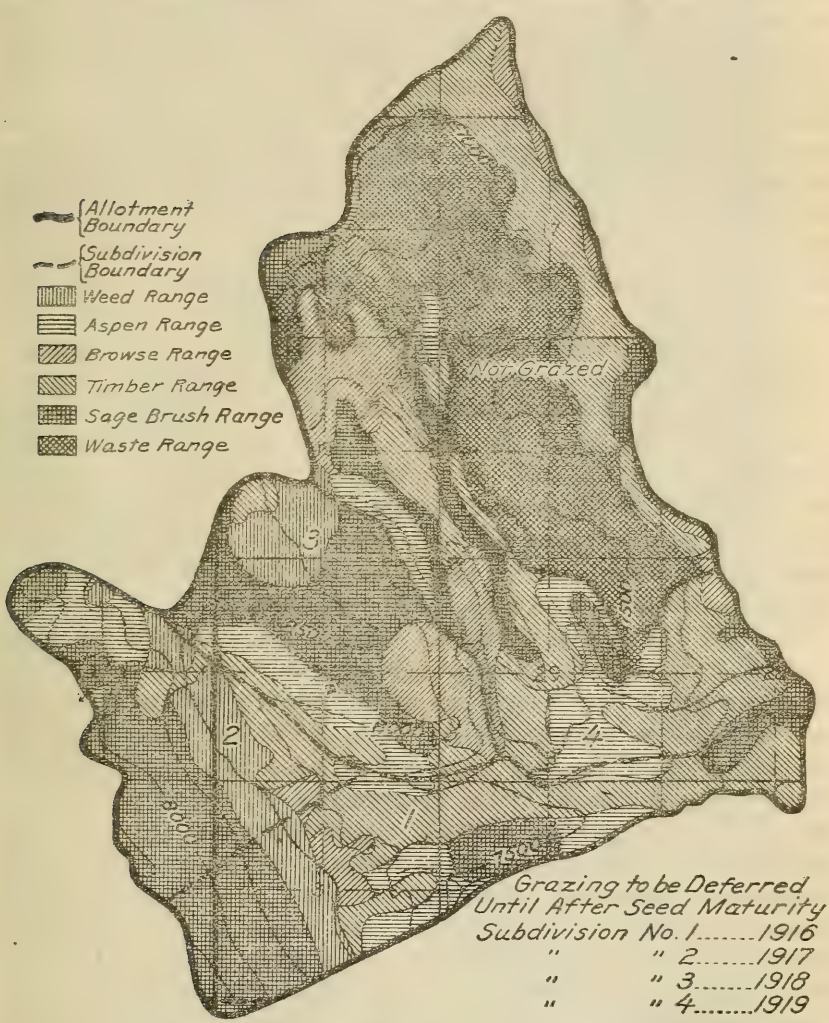


FIG. 4.—Range type classification and order of deferred grazing for a summer sheep allotment on the Caribou National Forest.

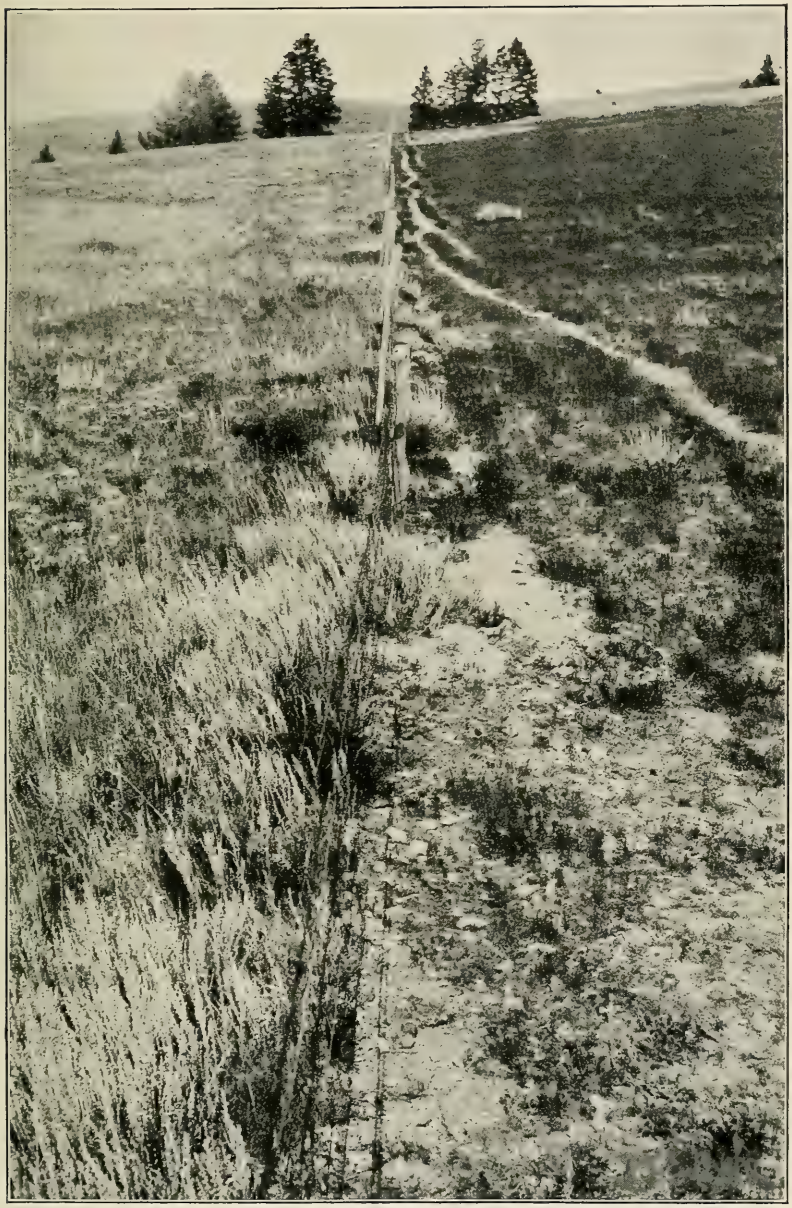
grazing capacity of the range in general will not justify the quantity of fencing necessary to control the stock on small areas. The first main division between spring and summer range, however, is essential and should be warranted, as only large areas are involved. It is worth thinking about and planning for, even if adequate control of stock can not be secured at once.

Where the spring cattle range is fenced off from the summer range there still is difficulty in securing adequate control of the cattle. It will probably be many years before division fences are built to provide for deferred and rotation grazing on small units, in accordance with the sample plan of this chapter. But cattle units ordinarily are large; and if they are kept large, as suggested in the paragraphs on Management of Cattle, deferred and rotation grazing should eventually be made possible by division fences on both spring and summer range. With this end in view, comprehensive plans for the future management of each cattle unit should be developed as soon as possible, so that fences constructed for other purposes will fit into the plan ultimately to be put into effect. At least, care should be exercised in the location of all fences to see that they will not interfere with the proper division and management of the range unit as a whole.

Meantime deferred grazing can be secured to a considerable extent on parts of cattle range in need of it by salting the stock away from the area to be protected, and in some cases by closing watering places on the area until after seed maturity of the important forage plants. Part of the stock accustomed to grazing the area during the early part of the grazing season will graze the protected area, regardless of insufficient salt and water, but a reduction of 50 per cent in the number that the area is supposed to carry will result in the protection of at least a part of the vegetation.

The problem of controlling the stock is not a difficult one in the case of sheep, so long as the range area to be grazed or protected from grazing is large enough to accommodate a band of from 1,000 to 1,500 head of ewes and their lambs under herding. On ranges of high grazing capacity, and not divided into small parts by canyons and ridges, to confine the band to the area represented by one-third of the grazing capacity might necessitate too close herding for the good of either sheep or range. Such a case might readily occur on a high, sparsely timbered summer range grazed only for about six weeks, or on a spring range which is of high grazing capacity, and used for only one or two months. In either case, however, the range involved is used from a number of central camps. Instead of using the camps in the same order every year, the order can be changed so that during a period of five or six years the range used from each camp will stand its share of grazing prior to seed maturity, so far as is consistent with the use of the range when the forage is suitable for sheep. Such a plan is shown in figure 3.

In a few cases the difficulty of adjustment has been overcome by using three or four sheep allotments as the unit for a system of deferred and rotation grazing, one allotment at a time being pro-



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The area on the left of the fence has been grazed heavily after the plants matured seed each year for a number of years. The area to the right has been grazed during the main growing season. Much of the vegetation to the right is weeds and grasses of secondary forage value. To the left the vegetation is mainly the best forage grasses of the region.

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Sheep "shaded up" in tree reproduction. Unwarranted injury to the reproduction may result from this practice.

tected until after seed maturity. This plan involves frequent redivision of range or departure from individual ranges for each band during the grazing season. It may work satisfactorily in some cases, but not generally. If it is necessary in order to build up an area, however, such a plan with its accompanying readjustments should be followed. The application of this plan would involve the substitution of allotments for the subdivisions in figure 4 and in the example given on page 61.

It would be difficult and perhaps unnecessary to discuss further the local problems to be overcome in applying deferred grazing. The suggestions given here and in the paragraphs on Grazing Periods and Grazing Capacity will make clear the importance of giving each portion of the range the maximum opportunity for unhindered growth after the growing season opens. Where possible a system of deferred and rotation grazing should be put into application. Where the application of such a system is not possible at the present time it should be provided for in working out future plans of management. Meantime, the period of using the range from a given camp on sheep range should be varied from year to year so as to distribute the early grazing as far as practicable. On cattle range, salting, closing water, and riding should be resorted to in the absence of fences to distribute early and late grazing; but the aim should be to have the cattle ranges grazed under a system of deferred and rotation grazing ultimately, as a means of maintaining the forage production under maximum grazing. Improvement varying from a few per cent to several hundred per cent has been brought about in partly depleted ranges as a result of following this system of grazing; and new evidence is available each season indicating that probably 25 per cent more stock can be carried on a range year after year under a deferred and rotation grazing system than on the same range with no effective provision for distributing the grazing prior to seed maturity, or no adequate provision for natural revegetation.

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GRAZING AND PROTECTION OF TIMBER, WATERSHEDS, GAME, AND RECREATIONAL USE.

POLICY.

"National Forests have for their objects to insure a perpetual supply of timber, to preserve the forest cover, which regulates the flow of streams, and to provide for the use of all resources which the forests contain, in the ways which will make them of largest service."[2] If the suggestions given in preceding sections on the fundamental principles generally applicable in grazing management are followed in practice, damage to the forests will be limited to individual cases where a combination of factors makes special treatment necessary to insure the proper protection of the timber resources and watersheds. On the other hand, the damage may be widespread and unwarranted if division of the range among different classes of stock, periods of grazing, grazing capacity, and management of the stock are not worked out with a reasonable degree of efficiency along the lines suggested.

PROTECTION OF TIMBER.

CONIFER SPECIES.

Through investigation and experience over a period of years a number of important principles have been developed for harmonizing grazing use with the production of timber. The intensive investigations on the effects of grazing upon the reproduction of conifer species have been concentrated mainly on western yellow pine. The suggestions based upon these investigations, however, will serve as a

[1] A few reprints available in Forest Service, Washington, D. C.
[2] U. S. Forest Service. The National Forest Manual; Regulations and Instructions.

guide in making necessary adjustments where other conifer species are involved.

Intensity of grazing.—The injury to conifer reproduction from grazing by any class of stock varies directly with the intensity of grazing. Hill[1] found in Arizona and New Mexico that "on overgrazed areas all classes of stock are apt to damage small trees (western yellow pine) severely. Cattle and horses may damage about 10 per cent of all reproduction. Where sheep are grazed along with them, however, at least 35 per cent of the total stand may be severely damaged. Ordinarily sheep cause about seven and one-half times as much damage as cattle." Under normal conditions of grazing, Hill found that "cattle and horses do an inconsiderable amount of damage to western yellow-pine reproduction, but that sheep may be responsible for severe injury to 11 per cent of the total stand of reproduction under about 4 feet in height."

Sparhawk[2] found in central Idaho that from 20 to 30 per cent of seedlings less than 1 year old were killed by sheep grazing and trampling on moderately grazed areas and 6.5 per cent on lightly grazed plots. On moderately grazed areas only about 1 per cent of the yellow-pine reproduction over 3 years of age was killed. Moderate grazing means removal of the greater part of the forage readily eaten by sheep.

Character of forage.—If there is an abundance of forage suitable for stock there will be little damage to tree reproduction by browsing. On the other hand, if there is little forage suited to the class of stock, especially sheep, the tree growth within reach will be browsed. This is why moderate grazing by sheep is defined as removal of the greater part of the forage readily eaten by sheep. Grazing until the less palatable forage is eaten will result in marked increase of damage to young tree growth, both from browsing and trampling.

Hill found that on range where the greater part of the forage is bunch grasses, sheep injured 32 per cent of the western yellow-pine reproduction under about 4 feet in height. The same intensity of grazing on range better suited to sheep resulted in severe injury to only about 10 per cent of the reproduction. The bunch grasses were not overgrazed, but they are not suitable for the main forage for sheep. Even light grazing would result in considerable damage to the young trees. Cattle on the same range would do little damage if overgrazing were avoided.

Time of grazing.—Both Hill and Sparhawk found that injury to tree reproduction is least when the range is grazed during the time

[1] Hill, Robert R. Effects of Grazing upon Western Yellow Pine Reproduction in the National Forests of Arizona and New Mexico. U. S. Department of Agriculture, Bul. 580, 1917.

[2] Sparhawk, W. N. Effect of Grazing upon Western Yellow Pine Reproduction in Central Idaho. U. S. Dept. of Agriculture, Bul. 738, 1918.

that the main forage is tender. This finding is in keeping with the conclusion that the extent of injury depends upon the supply of available forage suitable for the class of stock. When the herbaceous forage becomes dry and tough, sheep browse more on the young trees unless there is other browse more palatable.

Method of handling stock.—The way in which sheep are handled has an important bearing upon the extent of damage to tree reproduction both from trampling and browsing. Close herding, rounding up with dogs, driving in a close herd, shading up for long periods, and bedding more than one night in a place are all destructive to young trees. Such practices can not be followed without excessive trampling, which destroys a great many seedlings, or without grazing the forage suitable for sheep so closely that the sheep browse the young trees much more than they do where there is plenty of other forage. The damage will vary with the extent of bad management of the sheep, from injury which is not alarming to complete destruction of tree reproduction under 4 feet in height. If sheep are quietly grazed in loose formation, bedded only one night in a place, and given plenty of salt, the damage to tree reproduction will be kept at a minimum and ordinarily will not be alarming if the forage is suited to sheep and the range is not overgrazed.

When cattle congregate around water holes, salt licks, corrals, shading grounds along drainage, and at the edge of parks, they injure a great many young trees by rubbing. On 17 representative plots studied, Hill found 31 per cent of the trees between about 3 feet and 6 feet in height severely damaged. The damage can be reduced by proper salting, more watering places, and riding to keep the cattle properly distributed.

It is the general opinion that goat grazing is very destructive to young timber growth. Undoubtedly this is true where the range is heavily overgrazed and the goats are grazed from one camp throughout the entire year or for long periods. Three years' study of goat grazing, however, has resulted in data which indicate that a great deal of the damage may be charged to the methods of handling the range and the goats.[1] Goats prefer almost any other browse and green grass to conifer reproduction. If they are properly handled on range where there is ample forage, including browse and grass suited to them, they will eat little of the conifer reproduction. The old practice of overgrazing the range by goats and returning to one camp every night throughout the year or for long periods means death to the range as well as to the tree growth within reach. This practice should be stopped whether tree growth is involved or not. Goats should be handled under a system of open herding with fre-

[1] Chapline, W. R. Production of Goats on Far Western Ranges, U. S. Dept. of Agriculture, Bul. 749, 1919.

quent change of bedding ground. The bedding-out system of herding so widely adopted in handling sheep should be approached, if not adopted, in the handling of goats on the range. Unless these precautions are observed unwarranted injury to both range and tree growth may be expected.

ASPEN.

A study to determine the effects of grazing upon reproduction of aspen was conducted over a period of years on the Manti National Forest.[1] It was found that the leafage of young twigs of aspen is browsed in varying degree by both sheep and cattle. Sheep may be responsible for severe damage to aspen reproduction both in standing timber and on clear cuttings, regardless of the variety and supply of other choice forage. The damage from cattle grazing is usually slight, except where the range is overgrazed and around water, salt licks, and shading and bedding grounds where the cattle congregate.

Observations over a period of five years on range in standing timber showed that 27.2 per cent of the aspen reproduction under about 40 inches in height was killed by light sheep grazing; 31.8 per cent by moderate grazing; and 65 per cent by heavy grazing. On clear-cut plots the damage annually was found to be exceedingly heavy. Three years of successive sheep grazing on such plots following clear cutting of the standing timber resulted in complete destruction of the aspen reproduction. After the sprouts reach a height of about 45 inches, which takes about three years, they are beyond destructive browsing by sheep.

The foregoing conclusions apply, no doubt, to other central Utah Forests than the Manti. Observations elsewhere do not always show such marked damage from sheep grazing on range where other forage suitable for sheep is available. It is a fact, however, that overgrazing or heavy grazing by sheep will prevent a good stand of aspen reproduction. Continued overgrazing by cattle also will seriously interfere with, if it does not prevent, satisfactory reproduction.

It is imperative, therefore, to avoid overgrazing and mismanagement of the stock. In addition, only well-regulated, moderate cattle grazing should be allowed in clear-cut and thinned aspen forests during the first three years after cutting or thinning, if it is desired to secure a satisfactory stand of aspen reproduction.

IMPORTANCE OF PROPER MANAGEMENT OF THE RANGE AND THE STOCK.

In this whole problem of adjusting grazing so that it will not interfere to an unwarranted extent with timber production the foundation is grazing management and management of the stock.

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[1] Sampson, Arthur W. Effect of Grazing upon Aspen Reproduction. U. S. Dept. of Agriculture, Bul. 741, 1919.

If the range is used by the class of stock to which it is best suited, and the grazing and management of stock so regulated that range deterioration is avoided, the general damage to tree reproduction from grazing will not be a cause for worry, and the benefits from grazing, by a reduction of the fire hazard, will offset to a considerable extent the slight damage which may be done.

Perhaps there will always be special cases of reproducing cut-over areas, reproducing burned areas, plantations, and areas of special importance in standing timber, where special restrictions in grazing management will be necessary. Such areas are small compared with the total acreage of National Forest range. The difficult problem in such cases is to control the stock and apply the method of management needed without restricting grazing on other areas which might well be grazed. The solution will have to be worked out for the individual case by reduction in number of stock, change in class of stock, fencing to control or exclude stock, herding, water development, and proper salting.

WATERSHED PROTECTION.

One primary purpose of the National Forests is to preserve the cover which regulates the flow of streams. Cover in this sense includes the tree cover, the herbaceous and shrubby cover, and the surface soil with its decayed and decaying vegetable matter. This understanding of cover in relation to the regulation of stream flow is imperative in the management of grazing on the lands within the National Forests.

In open-stand forests the herbaceous and shrubby cover and the condition of the surface soil may be important factors controlling run-off. Where this cover is dense or comparatively dense, there will be little danger from grazing the forage as closely as it may be grazed and forage production maintained year after year. Where the herbaceous cover consists of a thin stand of bunch grasses and a few weeds, erosion and too rapid run-off may occur, even if the lands are not grazed. Light grazing under such conditions will probably not interfere with the regulation of stream flow; for there will not be enough trampling to pack the soil, there will be a slight increase in fertility from manure, and the stock will carry in seed to improve the stand of vegetation. Grazing that fully utilizes the forage on such areas, however, may result in packing the soil and decreasing its power of absorbing and holding precipitation. The conditions vary. No definite rule can be laid down, except that overgrazing must be avoided, even on small areas. If use is to be continued, the man on the ground must watch the results closely and adjust the management accordingly.

Vital portions of many important watersheds are untimbered or sparsely timbered. The maintenance of stability and regularity in stream flow under such conditions is dependent upon the maintenance of an herbaceous and shrubby cover and a surface soil which will be effective in preventing erosion and unwarranted run-off. Maintenance of an effective vegetative cover is imperative. No halfway measures will do, and it is unwise to allow deterioration at all, as erosion and soil depletion may start and be difficult to control. Overgrazing and too early grazing must be avoided. Deferred and rotation grazing should be applied, and stock should be properly distributed throughout the grazing period. These subjects have been fully discussed in preceding chapters.

The topography, the soil, and the character of the storms may be such that stability in stream flow can be maintained only by complete protection of the herbaceous cover and surface soil. Fortunately, the areas where complete protection against grazing is necessary are small and few in number as compared with the whole. However, they are usually distributed throughout larger areas of range in such a way that the only means of getting complete protection by control of the stock is to fence the small area or exclude stock from the larger unit involved.

Total exclusion of stock from a watershed might be recommended as a means of protecting vital parts of that watershed. This procedure could hardly be considered a solution, however, because in practice stock would be excluded from a large area which has been used for grazing for a number of years, probably only after conditions had become so bad that total protection from grazing would not, in itself, remedy the condition. A practical solution must stop the breaking down of the cover when the break begins and where it begins. The idea that injury resulting in marked erosion and rush of water from a small part of a watershed is warranted, in view of the great value of grazing on the complete watershed, is dangerous. Where such a condition is thought to exist a solution must be found which will give the necessary protection. Fencing of the critical area may be warranted rather than complete exclusion of grazing from the watershed as a whole. The cost of fencing as compared with the total value of the forage crop lost by exclusion of stock will be the basis for decision.

PROTECTION OF GAME.

Full discussion of the subject of game protection is not within the scope of this bulletin. The aim here is to make clear that protection and development of the wild life of the Forest must go hand in hand with the development and management of the range resources for use by domestic stock. In the first chapter, discussing the classifi-

cation of the range and its division between different classes of stock, it is pointed out that the forage habits of elk, deer, and mountain sheep are similar to those of cattle and sheep, and that, as a consequence, there may be conflict where a range as a whole is fully stocked or where either the summer range or the winter range of the game animals is fully stocked with cattle and sheep. It is obvious, therefore, that the needs of the game animals for range must be given more and more consideration as grazing by domestic stock becomes more intensive. There is the immediate problem of seeing that range is provided for the elk, deer, and mountain sheep already in any given locality. There is the future problem of providing for wider distribution of these animals and providing range for increased numbers in localities where an increase is desirable.

For either of these purposes it is necessary to know the number and distribution of game animals on each National Forest, the character of range necessary for the proper maintenance of each class, the area and grazing capacity of such range already available, and the need for increasing the present acreage or of restricting its further development for use by live stock. More accurate information on these subjects is vital to proper maintenance of the game without undue restriction of the development and use of the range by domestic stock.

Careful observations as to forage available for game animals will involve a study of the ranges in use by cattle and sheep as well as areas not used by domestic stock. The preceding chapters should make clear the difficulty of securing equal distribution of domestic stock over the range so as to use all the forage available. In the case of sheep, for example, forage must be in such quantity that it can be used by a band of 1,000 to 2,000 sheep under herding. Not infrequently small pockets of excellent feed, forage in dense brush and timber, and narrow strips of grasses, weeds, and browse along streams are not utilized by sheep because a band of sheep can not be handled on them. This feed, however, may be choice, both in character and location, for use by game. There may be enough range of this sort to provide summer feed for all the game animals which can be provided with forage or feed during the winter. This fact, or the contrary, should be established by a study of the situation.

The problem of winter range is more complicated. A great deal of the former winter game range has been taken by settlement, making it difficult in some localities for the game animals to live through the winter, even if there is little or no grazing by domestic stock. Where this is the case a thorough winter study of the winter game range should be made at the first opportunity. Such a study should be made by some one acquainted with the habits of game animals and having a knowledge of range. The big question is to determine

whether there is sufficient suitable forage available in places where it is practicable for game to use it without unwarranted loss of animals. During the course of such studies there will be opportunity to collect information as to the number and kind of game animals on the range.

Before opening up new range to domestic stock, the use, or probable use, of the area by game should be carefully considered. This precaution is of increasing importance as range management is perfected to secure more complete use of forage by domestic stock, both within the individual range unit and within the Forest as a whole. It is not intended that development of the grazing resources for use by domestic stock shall unduly restrict the development of game or interfere with its proper protection from loss due to lack of suitable forage. On the other hand, it is not intended that forage which might be used by domestic stock shall go unused for years if it is not needed by game. Each has its place in the development and use of the National Forest resources, and every forest officer should realize that he shares the responsibility of determining the proper relation between the two. The problem, so far as range is the deciding factor, is one for study and solution on the individual ranger districts.

RECREATIONAL USE.

The number of people who visit the National Forests for recreation is increasing annually, and it is probable that development along this line is only just beginning. This use of the National Forest lands as a general rule will not require any great reduction in numbers of stock or any great change in grazing management. On individual Forests, however, considerable readjustment of grazing may be necessary, and throughout the National Forests the grazing use of certain portions of the range may have to be adjusted so as to meet the needs of campers and summer residents.

Protection of camping places and forage for the work, saddle, and pack animals of campers is perhaps the most pressing need at present. Campers greatly outnumber the summer residents. The number which will visit any given locality in a given year and the time that they will appear is somewhat uncertain, and the length of time that they remain varies from year to year. It is certain, however, that suitable camping grounds should be provided and given sufficient protection from grazing to preserve their natural attractiveness. By careful selection and improvement of camp sites it will be possible to induce campers to use locations selected by forest officers. The establishment of a system of permanent camp sites will greatly facilitate adjustments in grazing so as to protect the camps and reserve feed near by for use by campers' stock.

The area which should be protected against grazing will vary and must be decided for the individual case. To insure the necessary protection against grazing on sheep range the area to be protected should be marked by posters. On cattle range it may be necessary to establish fenced public pastures in order to insure the reservation of feed at places convenient to the camp grounds.

Adjustment of grazing to meet the needs of summer residents, hotels, and summer resorts, for range and protection against stock, will have to be worked out in the individual case in accordance with the general policy of putting the lands to their highest use.

In the management of grazing as it relates to recreational use the essential thing at the present time is to realize fully the growing importance of recreation and to make provision for the necessary forage and protection of camp sites in working out plans for grazing management, especially where such plans involve opening up new range, increasing the number of stock, changing the class of stock, or the establishment of stock driveways, or where the grazing plan contemplates expenditures for permanent range improvements.

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RANGE RECONNAISSANCE AND RANGE INSPECTION.

OBJECT.

The objects of range reconnaissance and range inspection in a broad sense are the same. In either case the survey or examination of the range is made to collect information necessary for improving

[1] A few reprints available in the Forest Service, Washington, D. C.

or perfecting range management and utilization along the lines discussed in the preceding pages. The two differ in the intensiveness of the work and consequently in the degree of permanence of the maps and grazing-management plans resulting. Intensive range reconnaissance has been developed to a point where an adequate discussion of all phases of the work would itself fill a bulletin. The discussion here aims merely to make clear the essential differences between range reconnaissance and range inspection, the limitations and application of each.

RANGE RECONNAISSANCE.

An intensive range reconnaissance survey results in the preparation of a map classifying the area examined into grazing types, showing for each type the location, acreage, topography, amount, and character of vegetation, condition of the range, available watering places, and cultural features. The work is done with sufficient accuracy so that the resulting data will serve as the basis for present and future plans of grazing management, regardless of the intensity of grazing. The foundation for such a survey is a topographic map of at least reasonable accuracy. If a satisfactory topographic map has not already been prepared by some other survey, one must be made either in advance of or as a part of the grazing survey.

Range inspection is less intensive. If accurate topographic maps are available, a general grazing-type classification can be made during the inspection; but the detail of classification secured by the reconnaissance survey can not be secured by an examination which logically would be called a range inspection.

The range reconnaissance proceeds systematically; first in the collection of the field data, then in its compilation, and finally in the preparation of grazing-management plans, usually in the office, to be adjusted later in the field. Range inspection aims at sizing up a range unit in the field, finding the flaws in the existing management, and deciding upon the remedies, at the same time collecting sufficient data to point out the existing faults of management and show how to make the adjustments recommended.

It is possible to use men who have had but little preliminary experience in a range-reconnassance party under the direction of a well-trained chief of party; while on inspection only men who have had several years of experience in judging range can work effectively.

There is little doubt that surveys intensive enough to determine acreage by types to within an average error of about 5 per cent will eventually be necessary as a basis of intensive range management on fully stocked forests. This accuracy will necessitate a range-reconnaissance survey.

Figure 4 was prepared from a grazing-reconnaissance survey map. It shows the detail of classification into grazing types. The large waste area emphasizes the importance of determining the acreage and location of areas which are of no value for grazing, both in estimating grazing capacity and in planning use of the area of grazing value. The distribution and grazing capacity of the other types and the topography and water facilities furnish a good basis for deciding the important questions discussed in preceding chapters. Data on acreage, vegetation, and grazing capacity by types, ordinarily included on maps for grazing working plans, are omitted in the illustration.

At the rate intensive range reconnaissance will probably proceed many years will be required to cover the ranges within the National Forests. Meantime, much can be accomplished in correcting errors of grazing management by systematic range inspection.

RANGE INSPECTION.

The following outline will serve as a guide to the major questions which should be answered by the range inspector. As far as practicable in the time allotted for the inspection the field examination should be made with a view to furnishing the information desired for each small describable unit of range.

OUTLINE FOR RANGE INSPECTION.

1. Is the range unit being grazed by the class or classes of stock to which it is best suited? If not, by what class or classes of stock should it be grazed? The answer in each case should be in accordance with the suggestions given on page 3. Where maps are available the class or classes of stock to which each unit is best suited should be graphically shown. Photographs illustrating the topography and types should accompany this portion of the report.

2. Is the grazing season for each unit what it should be? If not, what is the proper period? Give dates. This classification also should be indicated on the face of the map used in the field, later to be shown graphically on the map accompanying the inspection report.

3. How does the intensity of grazing on the different range units compare? Such notes as will be needed in the preparation of a utilization map, showing areas overgrazed, areas not utilized, areas partly utilized, and areas fully or properly utilized should be made on the face of the field map and later shown by lines or colors on the map accompanying the inspection report. Also, the class of stock involved in each case should be indicated.

4. If the utilization is not what it should be on any one unit or number of units, what action should be taken to remedy the situa-

tion? Where a general movement of stock from one unit to another, such as from one grazing district to another, is recommended, the proposed shift should be shown on the map by arrow lines with figures indicating the number of animals to be moved. Proposed changes in allotment boundaries should be graphically shown if maps are available. Otherwise, written descriptions checked on the ground must be relied upon.

5. What is the grazing capacity of each range unit for the class or classes of stock to which the unit is best suited? To what extent is this estimate dependent upon changes in management? Grazing capacity can not ordinarily be determined conclusively in the field, but must be computed later from the figures and notations made on the face of the field map showing the relative stands of forage on the different units and the condition of the range and from available data as to the numbers of stock grazed at present and in the past.

6. Have adequate salting plans been developed for the Forest or the unit? While the details of salting must be left to the local officers, the inspecting officer should make general recommendations where necessary relative to the total supply of salt, based upon the grazing capacity, to be placed on each natural unit. The inspector should also offer any constructive criticisms that might aid the local force in bettering conditions in this respect.

7. Are the sheep on each allotment managed as they should be? Ordinarily an inspector will not have time to study the management of each band of sheep, but can gain in the course of inspection a very accurate idea of the methods employed on different parts of the range, and even on particular allotments, by observing the condition of the range with reference to the amount of trampling and the presence of bed grounds.

8. Is the tree reproduction being injured, and to what extent? The location of any extensive areas where injury has occurred should be indicated on the map, the class or classes of stock responsible being given. The map should be supplemented by notes giving the species and height of trees injured.

9. Are there any areas on which grazing has caused erosion? Indicate on the map the location of such areas and furnish notes describing the nature and seriousness of the erosion. If practicable, photographs should be taken.

10. What is the condition of the driveways on the Forest or range unit? Are they located to the best advantage for the protection of the Forest and the interests of the stockmen? Is there an opportunity to establish more driveways and follow some plan of rotation in their use? Should present driveways be widened and addi-

tional holding ground be provided? Is feeding along any driveway or portion of a driveway necessary and practicable?

11. Are there any game animals on the range unit? What kinds and how many? Where do they range in summer? In winter? Information on these points should be obtained from local forest officers beforehand and during the inspection to facilitate special observation on such areas as may need it. Is there any apparent or probable conflict between game animals and domestic stock in the use of the range? If so, what adjustments in grazing management should be made to insure adequate protection for the game? It is especially important to make sure that elk and deer have sufficient winter forage on areas suitable for their use in winter.

12. What range improvements are needed? Proposed improvements should be indicated on the map, and each should be discussed in a final report and plan, particularly with reference to the cost and the relation of the projects to forage utilization.

13. What is the condition of the improvements that have already been constructed? These should also be located on the map, and, if advisable, recommendations should be made relative to the nature and cost of maintenance work.

Everyone engaged in range inspection should collect information in the form of notes and photographs on all range improvements, such as water development, fences, bridges, corrals, trails, etc., that might be used either in bettering conditions in each specific case or in standardizing and improving this line of work in general. Proposed projects, projects under construction, and completed projects should be included.

14. What are the principal forage types and species on the Forest or unit under consideration? If the inspector is not already certain of the identity of the more abundant plants, specimens should be collected and identifications obtained. Ordinarily the inspecting officer will not have the time nor find it convenient to collect and care properly for more than 15 or 20 species in the course of an inspection. It is essential that notes on the abundance, distribution, and forage value of these species be made in the field while the inspection is in progress. These notes should be prepared separately from the remainder of the report. Where topographic maps are available the general division line between types should be drawn on the map.

15. What are the poisonous-plant species, and what is the extent of the losses in live stock from poisoning? Poisonous-plant areas should be located on a map, and recommendations should be made relative to the management of each area. These recommendations should contain figures on the acreage, the annual losses, and the cost of reducing or eliminating the losses on each separate area.

16. Is any part of the range in need of reseeding? If so, what plan must be followed to bring about the desired improvement? Ordinarily, these areas correspond to the overgrazed areas represented on the utilization map, making it unnecessary in most cases to prepare a special map showing the area of forest lands in need of reseeding.

17. Are there any areas where an intensive grazing reconnaissance is urgently needed to make adjustments in grazing management?

TYPE CLASSIFICATION.

In making an intensive grazing reconnaissance 10 different type divisions are used:

1. Grassland other than meadow.
2. Meadow.
3. Weed range.
4. Sagebrush.
5. Browse.
6. Conifer.
7. Waste range in dense timber and brush.
8. Barren, rock slides, cliffs, and denuded areas.
9. Woodland, pinion, and juniper.
10. Aspen.

These types are first indicated on the field map by numbers and symbols and later translated into colors. In inspection work the typing is greatly generalized, and each unit is given a type designation on the basis of the predominating species. The general aspect of the range is the best guide in determining this classification. The forage species are only occasionally conspicuous enough to contribute to the aspect of the range. If, for instance, a range supports enough aspen to make it at once apparent that this species is the most conspicuous, the area would be classified as an aspen type. There might be numerous grass or weed parks of considerable size that would be thrown into this general aspen type. In other instances a range might support sufficient sagebrush to give the landscape a general sagebrush aspect. The sagebrush might not be the most abundant species in the type, yet, because of its conspicuous habit, the area supporting sage should be classified as a sagebrush type.

FORAGE ESTIMATES.

Some means must be used to indicate the relative amounts of forage within each type and on different types. Ordinarily, this can be done best by the use of decimals. If the decimal 0.6 is used, this would indicate that there are 6 forage acres[1] for every 10 surface acres in the type. If the decimal 0.3 is used, this would indicate that the type supports 3 forage acres for every 10 surface acres, or only half as much forage per unit area as the first. These figures should be entered on the face of the map if the map used in making the inspection is fairly reliable. An estimate should be made and entered upon the map whenever there is a marked change in the stand of forage.

[1] For definition of forage acre see footnote, p. 27.

USE OF MAPS.

Preliminary to making a range inspection, all available and usable map data for the areas to be examined should be obtained and assembled. The maps should be enlarged or reduced to a scale of 2 inches to the mile, if they are not already this size; and they should be cut up and mounted on heavy cloth, in order that they may be folded into suitable size for carrying in saddlebags. If blue-line prints are available, these might be made on a specially prepared linen suitable for field use and satisfactory for later plans.

While on the ground, the inspector should make it a practice to record on the face of the map by the use of suitable figures, symbols, and abbreviations the most essential facts about range conditions. Such records, of course, must be occasionally supplemented by notes kept in a notebook that can be carried in the field.

In the absence of suitable maps the inspecting officer will often find it necessary to adopt some means of roughly determining distances and directions. This can be done on horseback by the use of a compass and tally register. In some instances a few prominent points might be located to good advantage by using a traverse board or plane table. The base for such a triangulation system must be a chained base line or previously established points which can be plotted.

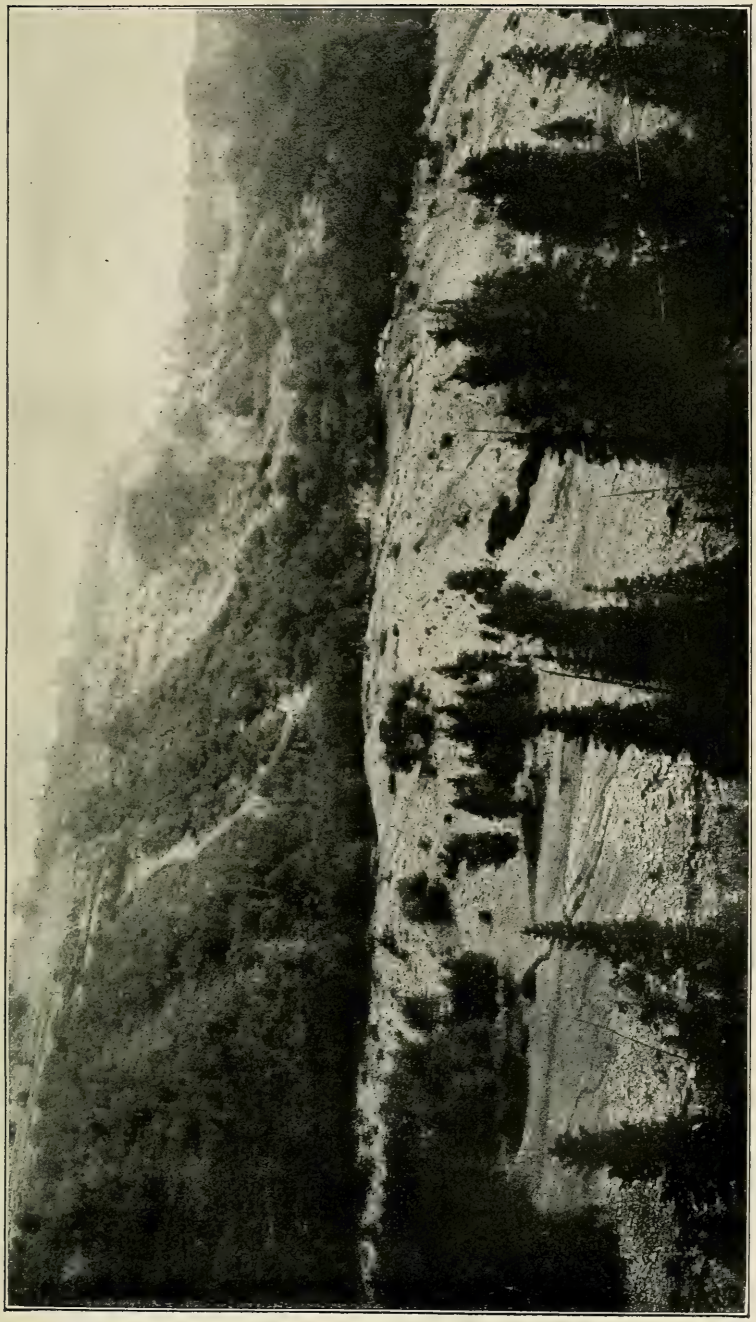
DEGREE OF ACCURACY REQUIRED.

The field work, as well as the work of arranging the data into usable form, should be sufficiently intensive and sufficiently accurate to serve as a basis for the solution of the principal grazing-management problems confronting the administration on the areas inspected.

If a forest is believed to be fully stocked, or even closely approaches that condition, obviously it would be inconsistent to base the relatively fine adjustments that would be necessary in such a case upon information obtained through a very general inspection. On forests considerably understocked the necessary adjustments might be made consistently on information obtained through a hurried inspection. On an intensively grazed forest of average size (800,000 acres) one man should spend at least the entire season, say from July 1 to October 31, in field inspection if satisfactory results for the Forest as a whole are to be secured. If there are any low ranges used for early grazing on the Forest, the inspection might begin late in May or early in June. This is usually the best time for the examination of lambing ranges and other early spring ranges.

TIME OF INSPECTION.

When there is a considerable variation in elevation the inspection should be planned so that each part of the range will be in practically the same stage of development when the examination is made.

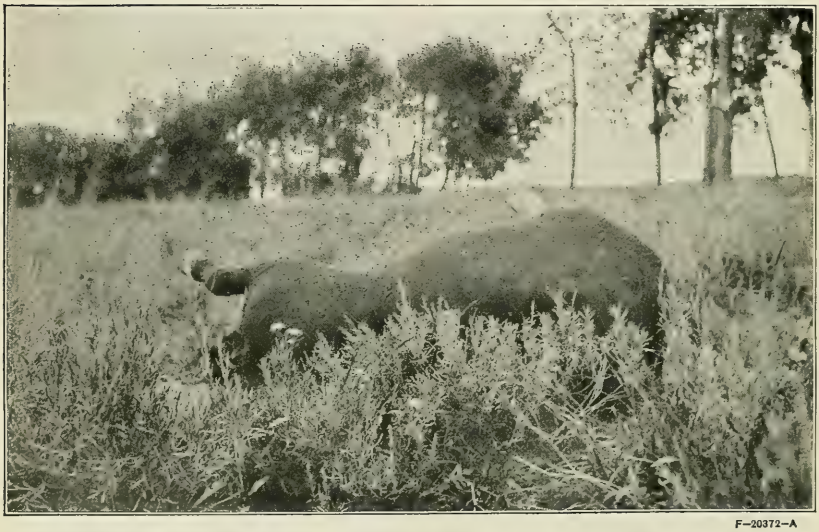


F-11773

Erosion, as a result of overgrazing, on an important watershed.

F—22597—A

Fig. 1.—A heavy loss of sheep from eating poisonous plants on the range. This loss could have been avoided if the poison area had been located in advance and the sheep properly handled.



F—20372—A

Fig. 2.—This animal died of larkspur poisoning. The market value of one good cow or steer in 1918 was about equal to the cost of grubbing out from 5 to 20 acres of larkspur.

The best conception of the utilization of the forage and the distribution of cattle for the current season can, of course, be gained during the latter part of the grazing period. For this reason, when an inspection is made for the primary purpose of determining the degree of utilization on each unit, the work should be done as late in the season as possible. Utilization classification for past seasons can ordinarily be made with a fair degree of accuracy very soon after the opening of the field season. The value of this information for the current season will depend largely upon whether or not the numbers of stock or the methods of management have been changed recently to any extent.

Where an inspection is made in the early part of the season, careful observations should be made for cattle signs of the previous season. Tracks are often reliable indicators, but the amount of manure left on the range is better evidence of the extent to which cattle have grazed the range the previous season or seasons.

When the matter of grazing periods is to be considered the inspector should be on the ground a short time before and during the time that the stock are coming on the range, in order to make observations relative to the amount of snow, if any, the condition of the soil, and the growth of the plants at this critical period. However, very reliable information can usually be gained from the local officers and stockmen relative to the condition of the range at the beginning of the grazing season.

COOPERATION OF STOCKMEN.

The successful application of the data obtained through a range inspection will ordinarily depend to a great extent upon whether or not the stockmen are willing to cooperate in making the resulting plans effective. It is seldom that a thorough inspection will not reveal changes which should be made, involving either redistribution of stock, readjustment in division or allotment lines, changes in grazing periods, or reduction or increase in numbers of stock. Whenever convenient, during the progress of the work, stockmen concerned should be informed that work of this character is being done. They will then be better prepared to receive whatever recommendations or plans result from the inspection.

The findings and recommendations resulting from the inspection can be presented and explained to the stockmen most effectively through the advisory board of the stockmen's association, where an association has been recognized by the Forest Service. If an entire forest or a large portion of a forest involving more than one association has been inspected as a unit, recommendations by the examining officer might be presented at a joint advisory board meeting.

COOPERATION OF LOCAL FORCE.

If the work is to be done by a special inspector, the local forest officers should be given a clear understanding of the purposes of the inspection and the methods that will be used.

It is seldom necessary or of advantage, however, for the special inspector to make himself familiar with administrative difficulties before the actual field work is done. A very general knowledge of the nature of these problems and the areas involved in each particular case is all that the inspector should attempt to get previous to the presentation of the essential information and recommendations based upon range conditions. The extent to which these recommendations can be immediately carried out is a matter to be decided by the administrative officers familiar with the various interests involved in each case.

The inspecting officer need not be accompanied by an administrative officer at all times during the inspection. A day or two with each ranger should be sufficient to give the inspecting officer a good idea of the best routes of travel and such other information as may be of use, and to give the ranger a good understanding of the inspection work.

PRESENTATION OF DATA.

It is necessary to separate large areas, such as a forest, into relatively small natural units before any satisfactory report or plan can be made. The size of these units depends to a considerable extent upon the intensiveness of the inspection; but ordinarily the units are made to correspond to the watersheds or portions of watersheds that can be given a name and for which the acreage in each case can be determined with at least a fair degree of definiteness. The unit of management for sheep is the band allotment; for cattle it is usually the community allotment.

Where considerable areas have been covered by inspection, and plans for the redistribution of stock are to be shown graphically, atlas-size sheets on a scale of 2 inches to the mile should be used.

Allotment boundaries with figures on the number of stock within each allotment, the acreage of each allotment with acres per head, and the permittee's name in each case should be entered directly on the face of the map or on a transparent overlay sheet that will make it possible to show the relation of the allotment boundaries to the topography.

POISONOUS PLANTS.

The best figures available show that about 6,000 cattle and 16,000 sheep are killed annually from eating poisonous plants on ranges within the National Forests.

Important facts relative to the main poisonous plants of far-western ranges have been accumulated as a result of field experiments, demonstrations, and observations under range conditions. Each of the main poisonous plants, the classes of stock poisoned by each, the season of poisoning, and the remedies, so far as they have been worked out, have been published and are available to every owner of live stock and every individual involved in the management of live stock on the range.

The publications listed at the close of this section should be read at the earliest opportunity as a preparation for effective work in the management of range infested with poisonous plants.

To master fully all available information on poisonous plants is only the first step. Until each poisonous species is recognized on the range and its distribution and abundance determined, little progress can be made in the application of measures, however practicable, to prevent the poisoning of stock. For poisonous-plant experts and range experts to attend to this themselves on the vast areas within the National Forests alone would take many years. Progress on a large scale necessitates not only that local forest officers and stockmen learn to know the poisonous plants when they see them on the range, but that they cooperate in locating all areas where each plant occurs and in determining the abundance of each plant on each area.

In this work the forest officers should take the lead. They are in possession of illustrated wall charts and pamphlets which will help in identifying the more important poisonous species. Colored illustrations for a number of species are in the library of every Forest. Specimens of the plants identified should be collected and forwarded to the district forester for check identification. The effort necessary is warranted by the magnitude of the losses annually and by the fact that only by such procedure will the men learn to know the plants with certainty and be able to reduce the losses and still use the infested range. Once forest officers know the poisonous plants on the range and know the information available relative to the class of stock poisoned by each species, the time of poisoning, the symptoms of poisoning, and the preventive measures, the interest and active cooperation of the stockmen may be developed. Then attention may be called to the plants on the range. Wall charts and mounted specimens may be used at meetings and lectures, publications may be referred to, and reading urged. Continued suggestion from a well-informed officer on the ground is the most effective way of creating interest and getting action.

When a dangerous area of poisonous plants is known to exist upon a forest, heavy losses may sometimes be avoided if the boundaries of the dangerous area are posted with proper warnings. Because it is often impossible for the local administrative officer to point out these

areas on the ground, it is highly important that they be posted as dangerous to the particular kind of stock affected.

Not infrequently there is a heavy loss of stock, apparently from poisoning, on areas not previously recognized as dangerous. If it is reasonably certain that the loss is due to poisonous plants, and the plants causing the loss are not known, some one should collect specimens of the plants not definitely known to be harmless and submit them for identification. The loss should be reported at once through the forest supervisor's office to the district forester, who will inform the experts on poisonous plants and request an examination of the area by an expert if possible. The collection of plants should not be delayed until it is known whether an expert will make an examination of the area. An expert is not always available at once, and by the time he reaches the area the plants responsible for the loss may be beyond identification.

The following suggestions apply to any range for the class or classes of stock given:

1. Don't overgraze the range. To do so may result in any class of stock's being poisoned fatally from eating plants which do not cause loss in the amount eaten when the range is not overgrazed.

2. When stock have been driven long distances without sufficient feed, or have been held off feed for any reason until they are very hungry, they should not be turned on range where plants poisonous to them occur in more than very small numbers. Their hunger can usually be satisfied first on parts of the range where there is no danger of poisoning. If no other way exists, and hay can be had, it will pay to buy and feed hay.

3. Cattle should not be salted near patches of larkspur. Areas near salting places are usually closely grazed, so that cattle eat more larkspur than they ordinarily would. Further, cattle have a tendency to loaf around salt and water and leisurely graze anything in sight. Losses of cattle from eating larkspur near salt grounds are sometimes attributed to eating too much salt.

4. Sheep should not be bedded more than one night in a place and should not be allowed to shade up for hours during the day on areas where there is more than a small quantity of vegetation poisonous to sheep. Vegetation suitable for sheep near a bedding ground is usually grazed off during the first night of bedding. The sheep then eat the poisonous species in harmful amounts. The same principle applies to shading grounds.

5. Stock should not be worried nor excited after they have grazed on a poison area. They should be moved quietly to an area where there is no poison and then left to rest or graze as they choose.

6. There is usually a short time during the grazing season when danger from poisoning is much greater than at other times. This

varies with different plants and for the same plants at different altitudes. The time of grazing should be adjusted as far as possible to avoid use of the poison areas during the most dangerous time. The stage of growth at which each of the important species is most dangerous to stock is given in the publications listed for reading.

7. Ample forage suited to the class of stock on a range is an important factor in keeping down loss from poisoning. Lack of more palatable forage results in the stock's eating more of the harmful plants than they ordinarily do where ample nonharmful forage is available. Following the suggestions under the section on determination of the class of stock to which a range is best suited will aid in overcoming this difficulty.

Departures from the practice outlined in these suggestions are not uncommon and are responsible for the annual loss of large numbers of stock.

Of approximately 6,000 cattle lost annually from poisonous plants within the National Forests, it is estimated that about 90 per cent are killed by tall larkspur.[1] The heaviest losses usually occur on small portions of the ranges. A hundred acres or less of tall larkspur within a cattle range unit of 15,000 acres may be responsible for an annual loss of stock great enough to discourage stockmen in the use of the range. Range, however, is valuable, and heavy expenditures on the small infested areas are warranted, if, as a result, an entire range unit can be made safe for cattle grazing.

During the years 1915–1917 tall larkspur was grubbed out on large cattle range units within 16 National Forests. A total of over 1,900 acres of larkspur was grubbed out at a total cost of approximately $11,000. By this expenditure more than a quarter of a million acres of cattle range has been freed entirely from loss of stock by larkspur poisoning, or the losses have been reduced to an occasional animal. The cattle saved in 1917, as a result of the grubbing work on 9 out of the 16 Forests for which reliable figures are available, were valued at nearly $16,000. The reduction in loss on the other seven Forests was considered equally satisfactory, but no actual figures are available.

The cost of grubbing per acre of larkspur has varied from $2.69 to about $13, depending upon the number of larkspur plants per acre, the amount of rock and gravel in the soil, whether the larkspur was growing in willows or brush, and the cost of getting men and supplies to the work. Whether the grubbing of tall larkspur from a given cattle range unit is warranted, however, depends upon the possible reduction of loss in cattle annually as compared with the total cost of grubbing and not upon the cost of grubbing per acre of larkspur.

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[1] Aldous, A. E., Eradicating Tall Larkspur on Cattle Ranges in National Forests, U. S. Dept. of Agriculture, Farmers' Bul. 826, 1917.

In some cases the total acreage and distribution of larkspur on a cattle range unit is such that grubbing is not practicable because of the cost, which, for the present at least, is excessive. Where this condition occurs a combination of grubbing, fencing, and herding may solve the problem. If it will not, and the loss is unwarranted, a change from cattle to sheep may be advisable.

The larkspur plants should be grubbed by cutting the main roots 6 to 8 inches below the surface of the ground. Some plants may be missed in the first grubbing, and others will grow from portions of the roots left in the ground. These plants should be removed by grubbing one year after the first work is done.

The grubbing can be done best as soon as the plants have made sufficient growth to be readily recognized. This varies with different localities and with altitude. Usually the work may start about one week after growth begins on the area in question.

A mattock with the spur cut off and the blade drawn out to about 9 inches in length is recommended for grubbing in loam soils. For rocky soils, a pick with one end flattened to 2 inches wide, or a combination pick-mattock has proved satisfactory.

The practical results from the grubbing work already done warrant every possible effort to determine the feasibility of grubbing out the larkspur on every cattle range unit where it is definitely known that cattle are killed annually by larkspur poisoning. The first step is to determine the value of cattle poisoned annually; the second step is to determine the acreage of larkspur and the approximate cost of eradication. In a great many cases grubbing will cost less than the value of the cattle lost annually from larkspur poisoning. In some cases it may be advisable to grub out the larkspur if the cost is as great as the value of the cattle lost in eight years.

Where fencing is the alternative, it should be remembered that maintenance of fences in mountain country is expensive and that if the fence is down or a gate is left open during the dangerous poison period the fence may fail to prevent loss.

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[1] Indicates that plant referred to is an eastern species and not found in the far Western States.

[2] With some of the older works it has not been possible to list the price of publications. Government publications are continually becoming "out of print" or available by reprinting, so that availability as indicated in the appended list can not at all be deemed final. Correspondence in all such cases should be addressed to the Superintendent of Public Documents and not to the Department of Agriculture.

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FORAGE PLANTS: COLLECTION, IDENTIFICATION, AND NOTES.

Familiarity with the vegetation which produces the forage crop on range lands is essential to their efficient management. Nearly every phase of range management is intimately associated with a knowledge of the range plants, their forage value for different classes of stock, and their requirements.

In determining the class of stock to which a range is best suited, character of forage is the first factor to be considered. In other words, the administrator of a range must have an accurate working knowledge of the plants on that range before he is in a position to decide the class or classes of stock to which the range is best suited.

The permanent welfare of the range is the fundamental principle in deciding the grazing period. At the same time it is important, so far as is consistent with normal utilization of the whole range and perpetuation of the desirable species, to utilize the plants at the periods of their highest palatability and nutritiveness, the latter

varying with the different important forage plants on the same area. A knowledge of the plant species on a range, their life habits and forage value, is almost imperative in order to know (1) whether the range is retrograding, improving, or stationary; (2) whether the good forage plants are being handicapped in the production of herbage or of a viable seed crop; (3) whether the important plants of a given range are being grazed sooner than they should be; and (4) whether there is loss of forage due to failure to utilize a species at its period of maximum palatability.

Four of the six so-called earmarks or indicators of overgrazing will be recognized only by those familiar with the plant cover. To recognize the worthless, transient, and undesirable species on a range and to differentiate them from the valuable, permanent, and desirable species is indispensable to a knowledge of what is going on on the range and the steps that must be taken toward improvement. The same is true of undergrazing. To tell with accuracy whether a range is producing the annual weight of beef, mutton, or wool of which it is capable the potential sources of forage must be recognized and a working knowledge obtained of the life history of the dominant species and their periods of maximum palatability.

It will be noted also that range management can not be worked out effectively until range divisions and grazing periods are established and the grazing capacity decided upon to a reasonable degree of efficiency. Now, range division, establishment of grazing periods, and estimation of grazing capacity all require a familiarity with the local forage crop. Fencing and salting also are often undertaken primarily because of local forage conditions. The signs of overgrazing are not at all always apparent to the observer who does not know the forage, for there may be a good or even luxuriant stand of unpalatable species taking the place of better forage that has succumbed as a result of grazing.

Injury to coniferous reproduction varies directly with the grazing intensity, and if there is abundance of forage suitable to the stock using the range there will be little damage to the timber reproduction.

The necessity of knowing plants poisonous to stock is evident. Even with the present means for dissemination of knowledge, there is still much need of education along these lines. On the other hand, accurate knowledge concerning the identity of our native poisonous plants is still meager. Undoubtedly many cases of poisoning on the range could have been averted had the toxic character of the plants responsible been recognized. For example, *Zygadenus* is often confused with grass or harmless liliaceous plants, or sheep are turned on to fruiting lupine. There is, undoubtedly, in some

places a waste of harmless umbellifer feed because of the rather widespread feeling that all these plants are poisonous. In fact, at least one case has arisen where a valuable forage plant, mistaken for poison hemlock (*Cicuta* sp.), was partly eradicated from a range, thus actually lowering the grazing capacity of the range in question.

For efficiency in the use of ranges it is not sufficient that a reasonable familiarity with the range species and their requirements be the exclusive possession of a relatively small group of men. Such information should be in such form as to be available to all persons in any way concerned in the use of the ranges.

The present system of plant collection, with identification at Washington by uniform, competent authority, and annotated report to the collector, has been probably the best means of familiarizing forest officers and stockmen with the identity, forage value, and requirements of the plants producing the forage crop on their respective National Forests. The main advantages of this system are:

1. A permanent record, always available for reference, is obtained in the specimens collected; and in the herbaria thus started forest officers and permittees have a constant means of authentic comparison for plants about whose identity they may be in doubt.
2. Accurate determination can be made of any plant which may be collected.
3. The identifications and nomenclature are uniform, so that the names for the same species are the same, regardless of the district in which the plants are collected.

In the identification of plants by botanists much importance is given to the so-called type specimen, that being the specimen on which the original description was based, very often the first specimen collected. It is sometimes impossible to tell positively whether a plant has been correctly identified until it has been compared with the type specimen; and, in the determination of plants, it is essential to have a herbarium of authentic specimens for purposes of comparison, because at best book descriptions are of little value to other than trained botanists. In a similar way small herbaria instituted on the National Forests form a permanent record of the local flora and furnish a constant means of authentic comparison with the plants the officers may encounter in their work.

An added advantage in having all the plants identified in Washington is that the benefit is obtained of the expert knowledge of a large number of specialists in the various groups of plant life.

Many of the ranges where plant collections are made are under different methods of management from those employed in the past, consequently more or less change in the vegetative cover is taking place. In cases of seriously overgrazed ranges there may be an entire change in the local flora, or even a series of successive changes, as the range is gradually restored to its pristine condition. A plant

collected to-day, therefore, with notes on its abundance and value, or lack of value, may prove to be an important record 30 years hence, when the species is no longer to be found on the range in question. In other words, without that specimen to fall back on one might not be sure in future years that certain definite changes of vegetation had taken place.

A plant specimen represents a not inconsiderable investment when the various processes through which it must go are taken into account, viz, collection, pressing, annotation, preparation for transmission, transportation, numbering, and arrangement in Washington, identification, recording and reporting, preparation and mounting for the herbarium, and fumigation or other protection from insects when in the herbarium. Attention to certain details in connection with the collection of the plants will tend to produce a maximum of beneficial results with a minimum of ultimate expense. A poor specimen may cost practically the same as a good one, yet there is a great difference in the value of the two as records.

SUGGESTIONS FOR THE COLLECTION OF RANGE PLANT SPECIMENS ON NATIONAL FORESTS.

SELECTION OF SPECIMENS.

The plants should be collected during their flowering or fruiting stage; and, wherever practicable, the whole plant should be collected. As the sheets for mounting the specimens are 11½ by 16½ inches, all specimens should come within these limits. If the plant is too large to be preserved in its normal position, it should, if possible, be bent, preferably in Λ, N, or M shape, to bring it within the proper dimensions. If the plant is too large to preserve in its entirety, representative portions will have to be selected. It is often desirable, especially with grasses, to hold the corners securely, when bent and placed in the press, by means of small pieces of cardboard in each of which a slit about an inch or two long has been made. Grasses should not be bent at the "nodes" or joints.

A plant specimen, to be complete, should include not only representative portions of the parts above ground, but also enough of the underground parts to indicate clearly the character of the root system. It is often impossible to obtain all these parts in a single specimen, so two or more specimens should be collected when necessary. When this is done, care should be taken to see that these several portions are kept together in the collection and that they receive but one number, or, preferably, that they be placed in the same folder. Complete specimens are often necessary for certain identification and are always desirable from the purely educational standpoint. Many specimens are unidentifiable specifically because, al-

though in flower or in fruit, they lack stem leaves, basal leaves, or roots. Numerous plants, including the great majority of sedges and rushes, as well as a large number of borages, crucifers (mustards), umbellifers (parsnips), and other plants, are unidentifiable, at least as to species, without mature fruits. Whenever practicable, both flowering and fruiting specimens of leguminous plants, especially lupines and loco weeds, should be submitted. The identification of lupines and loco weeds is often difficult, and the presence of both flowers and pods is sometimes necessary for certain determination. Many others, for example, *Ceanothus*, are unidentifiable without leaves, and a few, such as water hemlocks (*Cicuta*) and larkspurs, are more or less dependent on roots for their certain determination.

In collecting specimens of trees and shrubs, the sprays selected should represent the common leaf and fruit forms. With tree specimens small squares of the bark should be obtained whenever convenient; 2 to 4 inches square is sufficiently large.

All earth should be removed from the roots of specimens before they are placed in the plant press. If the plant is collected in a wet site, the roots can readily be washed off. If the plant grows in a dry situation, the earth can readily be removed from the roots by tapping them gently on the boot heel. Loose soil and grit in the folder, which is inevitable when the roots are not properly cleaned, will work into the specimen and not only render it unsightly, but will often so seriously injure the more delicate structures that identification is made difficult, or even impossible. All plants should be collected in triplicate or quadruplicate.

METHOD OF DRYING.

It is necessary to press the plant specimens so that the parts will be flat instead of curled up when dry, otherwise they will be worthless for a permanent record, and either absolutely unidentifiable or else identifiable with difficulty.

The specimens should be placed between folded sheets of plain absorptive paper, preferably the thin white containing sheets known as species folders. It is desirable that the standardized species folder, 16½ by 23 inches, be used for this purpose, as a standard size and quality facilitate handling. If it is necessary to use folded newspapers in the field, the plants should be transferred to a folder without printed or written matter; otherwise, each folder will have to be looked over carefully for possible notes before it can be discarded; and, besides, it is difficult to number such sheets or write the name of the plant on them and have such data stand out clearly. When the plants are ready for pressing, the sheets containing them should be piled alternately with sheets of blotting paper and placed between

boards or in a wicker press and subjected to a pressure of 45 to 65 pounds; this is usually applied by tightly drawn straps or by a weight, not heavy enough to crush the tender parts of the green specimens, yet not so light as to allow the leaves to wrinkle in drying. Stems, roots, and other parts more than a quarter of an inch in thickness should be thinned on the back with a knife before pressing. The blotters should be changed each day, well-dried ones being substituted; this is necessary, of course, to prevent molding and blackening. In most cases, except, perhaps, with fleshy or woody plants, the specimens will be thoroughly pressed and dried in about a week.

NUMBERING.

The specimens should be numbered consecutively. It is desirable that the collector should not duplicate his numbers by beginning each season with No. 1, but that he should have his numbers continuous from year to year. Many forest collections sent in for identification contain specimens of several collectors, and in this way duplications of numbers often arise. The duplication of numbers, with the impossibility of distinguishing between them, renders a report on the collection without the return of the specimens valueless. All joint collections, therefore, sent in as one collection from a Forest, and in which the collectors' numbers more or less overlap, should either have the collectors' numbers modified (by a prefixed initial or in some other way) or else be given forest numbers in addition to the collectors' numbers. Otherwise, when a report on the collection is received from Washington misunderstanding is bound to ensue.

NOTES.

FORMS.

System in collecting notes and expedition in examining them are greatly aided by the adoption of a form for this purpose. Futhermore, such a form makes the most valuable kind of herbarium slip for mounting with the specimens. These considerations have led to the adoption by the Forest Service of Form 767, and this form, properly filled out, should accompany all range-plant specimens submitted for identification.

Data should not be recorded on the back of the form, as not only are they apt to escape notice entirely, but they will be completely hidden when the form is pasted on the mounting sheet. As the form is intended for a permanent record, it is essential that the data be legible, and it is desirable that the appearance should be neat; therefore typewriting or pen and ink is preferable to pencil, as a hard pencil will make the record faint and a soft one will make a record which is very apt to blur badly, especially when the form is being

pasted. In preparing duplicate or multiple forms care should be exercised to see that the forms carboned or otherwise duplicated are properly centered, for if this precaution is neglected the data on the copies will be wrongly lined.

The forms should preferably be placed loose in their appropriate species folders or fastened by clips thereto, so that they may readily be removed for subsequent attachment to the mounting sheet.

ADDITIONAL DATA.

If more notes are obtained than can be conveniently placed on Form 767, such data should be written separately, preferably in single-spaced, short-lined typewriting and on one side only of a good quality of white paper, in order that such information may be filed permanently on the mounting sheet with the specimen itself and Form 767. If the data are too extensive for this, they should be written on white cards 4 by 6 inches, notes for only one species on a given card.

PLANT CATALOGUE.

The use of a plant catalogue, while no longer mandatory since the adoption of Form 767, offers many advantages and is to be encouraged. Many Forest Service collectors make their plant notes in the field in the notebook designated "Plant Catalogue," and their Forms 767 are made up in the office from these plant-catalogue notes.

The plant catalogue should contain as much of the following data as it is possible to collect, especially in the case of valuable and abundant plants:

1. Collector's number.
2. Botanical name.
3. Common or local name.
4. Date of collection.
5. Exact location.
6. Habitat.
   - (*a*) Altitude.
   - (*b*) Kind of soil.
   - (*c*) Moisture conditions.
   - (*d*) Slope and exposure.
   - (*e*) Forage type with its forage density.
   - (*f*) Associated species.
7. Dates when flower stalks are sent up.
8. Dates when seeds mature, disseminate, and germinate.
9. Seed habits—prolific or weak.
10. Distribution and abundance.
11. Palatability to various classes of stock and period grazed.
12. Any striking characteristics.
13. Remarks as to management.

IDENTIFICATION OF THE SPECIMENS.

The reasons for uniform identification of all plants in Washington were presented on page 90. These determinations are made by experts of the United States Department of Agriculture. Many of the plants, such as grasses, sedges, rushes, willows, hawthorns, lupines, currants, and heaths, go to specialists. Furthermore, plants from particular regions, such as Utah, New Mexico, and the Blue Mountain

district of Oregon, are identified, or at least check-identified, by the authors or prospective authors of floras of those localities, who are botanical authorities for those regions.

REPORTING ON THE COLLECTIONS.

In reporting on a collection from Washington a list will be furnished of the identifications as determined by the experts, arranged alphabetically according to four groups; viz, grasses, grasslike plants (mostly sedges and rushes), nongrasslike plants (exclusive of trees and shrubs), i. e., herbs or weeds, and trees and shrubs.

So far as possible, economic notes for the species in the collection will also be furnished. Notes for the grasses are available in printed form. The notes collated in Washington cover the following points: Range, botanical description, habitat, periods of flowering and of seed dissemination, reproduction, and forage value. While every care is taken to have these notes accurate and helpful, it is obviously impossible for any one man, or even group of men, in Washington, from personal observation or research, to know the habits and values of all the species comprising the forage crop of so vast a region as that covered by the National Forests. Such knowledge is necessarily cumulative, the product of the observations of many men in many fields; its attainment will necessitate the cooperation of the entire field force of the Forest Service.

MOUNTING FOR THE HERBARIUM.

Plant specimens are most convenient for reference when mounted and systematically filed in a herbarium.

Specimens are mounted by fastening them securely to white cardboard or linen-ledger mounting sheets. Some prefer to glue the specimen to the mounting sheet. This method has the advantage of expedition and cheapness, but it causes more or less injury to the specimen, and the specimen can not be removed nor remounted, as is not infrequently desirable, without great difficulty and without injury. The more satisfactory, though somewhat more expensive, way of mounting is to use narrow strips of adhesive tape, preferably surgeon's isinglass plaster (on silk). Thick and heavy mounts, such as woody specimens, may require sewing, or, if desired, the use of fine copper mounting wire, to make them secure. Care should be taken to see that the ends of the specimens are rigid; and, in the case of twigs and stalks, which, unless properly mounted, are easily pried off or broken in handling, the mounting plaster should be placed close to the cut or broken end of the specimen. The mounting plaster should always be placed at right angles to the stem or other part mounted and be of proportionate width; it should be pressed firmly to the mounting-sheet surface until complete attachment is assured. Curved botanical forceps or tweezers for exerting

pressure on the mounting plaster in mounting will be found superior to the unaided fingers. Flowers or other parts essential to identification should not be hidden by the mounting plaster.

Small loose material, such as fruits, seeds, and leaves, which may be needed for further study, should be inclosed in a small envelope in such a way as to be conveniently opened, in some corner of the mounting sheet.

Plant specimens for Washington should not be mounted.

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CONTENTS BY HEADINGS.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 791

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C. PROFESSIONAL PAPER August 27, 1919

PLANT SUCCESSION IN RELATION TO RANGE MANAGEMENT.

ARTHUR W. SAMPSON, *Plant Ecologist.*

CONTENTS.

THE PROBLEM.

The carrying capacity of a large portion of the millions of acres of western range has been materially decreased by too early grazing, overstocking, and other faulty management. Stockmen generally recognize this fact and are doing what they can to overcome these faults in management and to increase the productivity of the range. Where grazing has been subject to regulation for some years and the stock has been handled according to most approved methods the productivity of the range has been appreciably increased.

One of the most serious drawbacks in the past has been the lack of a means of recognizing overgrazing in its early stages. In deciding upon the lands especially in need of improvement, the stockmen and those regulating grazing have essentially relied upon general

observations of the abundance and luxuriance of the forage supply and upon the condition of the stock grazed. The depletion of the lands is seldom recognized by these general observations until their carrying capacity has been materially reduced, or until the animals grazed are in poor condition of flesh. So long as the cover is more or less intact, there is little indication that the range is being slowly but certainly depleted; the depletion is not recognized until the more palatable and important forage species are in low vigor, and their growth and reproduction seriously impaired, or perhaps not until a large proportion of the plants actually have been killed. Until there is insufficient feed to support the animals, they will retain their condition of flesh fairly well; but long before there is insufficient feed to satisfy their appetites a large portion of the vegetation is killed. To reestablish the stand after impoverishment has reached such an advanced stage requires many seasons of most skillful management.

Enterprising stockmen and those concerned with the administration of grazing know that the live-stock industry has now reached a point where the intensity of the use of the forage crop must be governed by a finer discrimination than mere observation of the density of the plant cover and the condition of the stock. The margin between what clearly constitutes overgrazing and what is clearly undergrazing must be reduced to a minimum if the lands are to be utilized within from 10 to 20 per cent of their maximum carrying capacity and the herbage cropped on the basis of a sustained yield.

The most rational and reliable way to detect overgrazing is to recognize the replacement of one type of plant cover by another. Certain more or less temporary species almost invariably succeed the more stable weakened or killed plants on lands that are being overgrazed, hence the incoming species are the most reliable indicators of small departures from the normal carrying capacity of the range.[1] It is the object of this bulletin to point out what plants are reliable indicators of overgrazing in the various types and how they may be used as guides in revegetation and the maintenance of the forage crop.

SUCCESSION OR THE DEVELOPMENT OF VEGETATION.

In studying the laws underlying the occupation of lands by vegetation from its earliest stages to the development of the highest type of plant life which the habitat is capable of supporting, a somewhat

[1] Shantz, H. L. (Department of Agriculture Bulletin 201, 1911), Kearney, T. H., Briggs, L. F., Shantz, H. L., McLane, J. W., and Piemeisel, R. L. (Journal of Agricultural Research, 1: 365–417, 1914), and others, have shown that the character of the native vegetation affords a reliable index of the conditions favorable or unfavorable to the production of farm crops, and have incidentally established correlations between the native vegetation and the available moisture and the physical and chemical properties of the soil. Relationships between the native vegetation and the carrying capacity of range lands have been developed through the investigations here reported, application of which appears to be of far-reaching importance in the judicious management of the lands.

regular replacement of one type of plants by another is found. This phenomenon, known as succession, is explained on the basis of certain more or less distinct changes that take place simultaneously in the substratum and may be accounted for in various ways, probably the most influential and universal cause being the addition of humus.[1] The plants themselves, by adding humus to the soil through the decomposition of their tissues, and in this way changing the physical and chemical composition of the soil, prepare the way for a new and higher form of life, hence in a way work out their own destruction. Accordingly, quite different plant types are recognized on soils in different stages of formation. The characteristic types are shown graphically in figure 1.

Beginning with the bare, consolidated rock, the first vegetation consists of such inconspicuous, uneconomic forms of plant life as algæ and crustaceous lichens. These forms mark the initial or pioneer stage of development. Occasionally, amid the somewhat thickened cushion of moss growth or in the crevices of the rocks, an early-maturing annual herb will find its way. This consociation of lichen, moss, and herb is characteristic of what may be termed the "transitional" stage of development; and so far as humus, soil moisture, and wide spacing of the herbaceous plants are concerned, it is not dissimilar to desert conditions. Like annual plants of the desert, the initial herbs must be able to germinate and grow to maturity in the shortest possible period and with the use of a minimum amount of moisture.

At the advent of the first-weed stage, which, typically, is characterized by a semidecomposed soil, poor in organic matter and relatively low in available moisture content, there is a distinct predominance of shallow-rooted, early-maturing annuals. At first widely scattered, the annuals gradually become more numerous, so that finally, as more and more soil is preempted, there is a cover well-nigh completely clothing the soil surface during the period of maximum seasonal development (Pl. I). As soon as this vegetation has reached maturity, or when growth has been arrested by frost or other adverse conditions, the greater portion of the soil surface is at once exposed. It is then that the casual observer notes, possibly for the first time, that a few aggressive, drought-resistant,[2] short-lived perennial grasses and weeds have invaded the habitat. This stage of development affords a small amount of inferior forage if utilized at the proper time.

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[1] This statement refers only to the evolutionary development of vegetation. The transformation from a complex to a more simple or earlier vegetational stage will be considered later.

[2] A drought-resistant plant, as here used, implies a species which is a conservative user of water and which can complete its growth cycle under conditions of low available soil moisture content and under trying atmospheric conditions.

The second-weed stage is characterized by a fairly well decomposed soil. The improved condition of the rock as a habitat for plants which results from the formation of soil is obvious. This is particularly evident when we recall that the rate of succession is largely determined by the moisture conditions of the substratum.

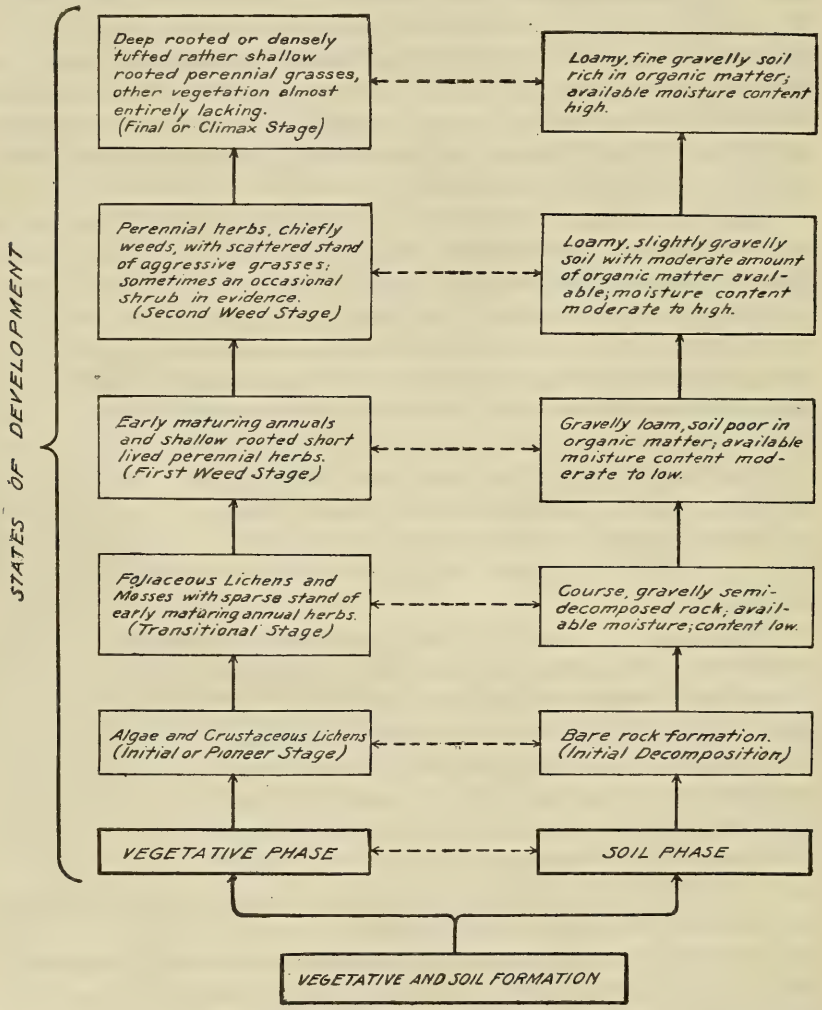

FIG. 1.—Plant succession or the development of vegetation where grass constitutes the climax or subclimax type.

The soil upon which the second-weed stage develops, being moderately well impregnated with organic matter, is fairly moist throughout the growing season. This condition permits the establishment of a stand of perennial herbs of varying density, the weedy, unpalatable species often predominating. These, in addition to an admixture of bunch grasses and often of turf-forming species as well,

give character to the landscape, and the interlacing roots and rhizomes bind the soil somewhat firmly, though at this point of development the grasses are not sufficiently abundant to form a sod.

By the time the second-weed stage has had its growth and has thus prepared the way for the next set of plants the soil is sufficiently decomposed and contains sufficient organic matter and soil moisture to make possible the establishment of the climax or the subclimax grass cover.[1]

In the utilization of lands as grazing areas, the invasion by the higher type of vegetation is often prevented, especially where the species high in the development are grazed with greater relish than those lower in the succession. Thus the plants well up in the development of the type may disappear gradually or suddenly, according to the degree of disturbance caused by the adverse factor, until the plant stages lower in the development predominate. If the factor adverse to the progressive development of the vegetation continues to have its play for an indefinite period the vegetation will continue to revert until the first-weed stage reappears, or, indeed, until practically all the soil is carried away and the pioneer stage returns. Such a succession of the plant cover down the scale from the more complex to the primitive type will be referred to in this bulletin as retrogression,[2] retrogressive succession, or degeneration.

The destruction of the entire soil formation and the exposure of consolidated rock occurs only in the worst possible cases. More commonly the productivity of the soil is decreased to a point where it

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[1] Areas well within the woodland type are often occupied by a temporary cover in which grasses constitute the herbaceous climax. Within a woodland formation, however, grasses seldom if ever hold their own permanently against the invasion of timber species as they do on prairie and plain.

[2] The writer's concept and use of the term "succession" differs from that of some ecologists (e. g., Clements, F. E., "Plant Succession, an Analysis of the Development of Vegetation," Carnegie Inst. Wash. Pub. No. 242 : 161–167, 1916) in that both progressives and retrogressive succession are recognized. Coming as it does from the Latin verb "succedo," meaning literally "I go under," the word "succeed" originally had nothing to do with the superiority of one crop over another. Thus, succession is here considered in the sense to "follow," "take the place of," etc., and is applied in a vegetative invasional sense. Accordingly, if the developmental trend of an association or other plant unit is ascending toward the climax, it may be referred to as a positive or progressive succession; if descending from the climax it may be termed a negative or retrogressive succession. Regardless of whether retrogressive succession occurs in the same specific descending series as it has been recorded to occur in the ascending development toward the climax, the use of the term "retrogression" or "retrogressive succession" is a convenient and self-explanatory term, and its use in no way involves a fundamental principle.

For a further discussion of the subject of progressive succession the reader is referred to:

Cowles, Henry C., The Physiographic Ecology of Chicago and Vicinity. Botanical Gaz., vol. 31, No. 2 : 73–108, Feb., 1901.

Moss, C. E., The Fundamental Units of Vegetation. The New Phytologist, vol. 9, Nos. 1 and 2 : 36–37, Feb., 1910.

Hole, R. S., On Some Indian Forest Grasses and Their Ecology. Indian Forest Memoirs, vol. 1, No. 1 : 13–16, 1911.

Sampson, Arthur W., Succession as a Factor in Range Management. Journal of Forestry, vol. 15, No. 5 : 593–96, May, 1917.

can support only vegetation characteristic of the first-weed stage; in still more common instances it may support an admixture of annual and perennial weeds of the first and second vegetational stages.

While changes in the ground cover from a more or less permanent (subclimax) type of high forage value to an unstable or temporary one of low forage value, may be brought about in many ways, overgrazing or other faulty management is usually accountable for the retrogression in the vegetation on range lands as a whole.[1]

The grazing of live stock may either appreciably change the original palatable vegetation, for instance, transforming a pure grass cover to a mixed grass and weed consociation; or it may cause an entirely new plant cover to come in, as is almost invariably the case on denuded grazing lands. The character of the vegetation following denudation is largely determined by the topographic features and the seriousness of the depletion of the soil as a result of erosion or other adverse factors. On level areas, if they are not subject to severe wind or sheet erosion, the climax vegetation is sometimes destroyed without appreciably changing the fertility of the soil or its available water content. Where the fertility of the soil is not appreciably lowered, the higher type of vegetation reappears without the more primitive forerunners, or the intervening successional stages are short-lived and more or less intermixed with the climax species. But on the hillsides or other exposed, readily drained lands, where the upper, fertile layer of soil has been much depleted and its water-holding capacity greatly decreased, and a large proportion of the soluble salts and other plant foods carried with the water down the drainage channels, the plant cover is thrown back to shallow-rooted, early-maturing annual herbs, similar to those characteristic of the first-weed stage (fig. 1 and Pl. I).

The time required for thorough revegetation of lands where retrogressive succession has taken place is approximately in direct proportion to the degree of depletion of the soil, hence to the stage of vegetation which the soil is capable of supporting, so long as the climatic conditions, topographic features, and type of soil remain the same. On range lands the rate of progressive development, or revegetation, may be greatly expedited by cropping the herbage in such a manner as to interfere as little as possible with the life history and growth requirements peculiar to the different successional plant stages. Accordingly, the best results in promoting progressive succession are obtained where the season of grazing is determined on the basis of

[1] Factors such as the formation of a road or trail, the colonization of a prairie dog town, and the like, may greatly change or even destroy the vegetative cover, but the effect of such factors is seldom far-reaching economically as compared with faulty management of live stock.

the life history of the different species, and notably upon the time of seed maturity.

THE PLANT TYPES.

Following the general classification of the successive plant stages, both in the building up and in the deterioration of the range, an intensive study of the succession of the vegetation was carried out on overgrazed protected areas, on overgrazed unprotected areas, and on undergrazed depleted lands, the quadrat method being used.

The investigations were conducted in the vicinity of the Great Basin Experiment Station, located in that part of the Wasatch Mountains embraced by the Manti National Forest in central Utah. The area studied lies between about 9,000 and 11,000 feet in elevation in the spruce-fir type—in the subalpine (Hudsonian) zone—which includes the typical summer range. In flora and climate this region is somewhat intermediate between the extremes of the Northwest and the Southwest. Broadly considered, the species making up the predominating vegetation are similar to those conspicuous on the summer ranges included within the National Forests in northern New Mexico, Utah, western Colorado, and parts of Idaho and Nevada; and the conditions in the high mountain ranges generally are such that the principles involved will apply elsewhere.

Careful grouping of the vegetation up and down the scale of development into divisions which can be readily recognized and used in applying the principles here set forth reveals four major stages of vegetation. These stages embrace all the lands which receive their moisture directly from precipitation, but do not include the relatively small acreage of marsh lands and other similar areas.[1] The plant stages from the subclimax down to the most transitory cover are as follows:

The wheat-grass consociation (subclimax stage).
The porcupine-grass-yellow-brush consociation (mixed grass-and-weed stage).
The foxglove-sweet-sage-yarrow consociation (second or late weed stage).
The ruderal-early-weed consociation (first or early weed stage).

In order fully to appreciate the significance of the changes that take place in the development of the vegetation either toward or away from the subclimax type, as well as the significance of the component consociations in their relation to the management of the range, it is essential to know the ecological peculiarities and economic value of each.

[1] Justification for the elimination of wet meadows and similar areas is found in the facts that such lands are limited in extent, and the forage which they produce is rather inferior, and is seldom grazed destructively.

THE WHEAT-GRASS CONSOCIATION.

The wheat grasses (*Agropyron*), broadly considered, constitute the climax herbaceous cover. In the vegetative cover as a whole, however, the wheat grasses are the subclimax type, the timber species, of course, constituting the true climax.

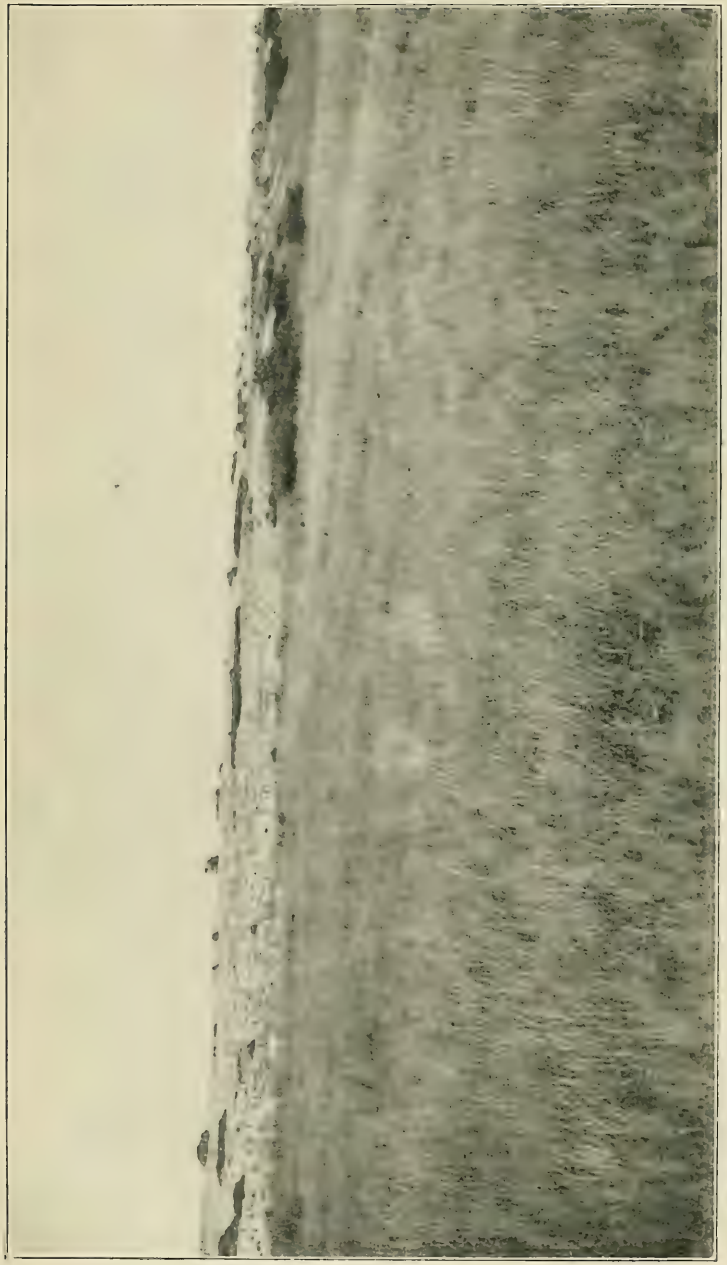
In its unhampered development the wheat-grass consociation occupies all well-drained timberless or sparsely timbered areas in the subalpine belt, where the soil is well decomposed and of at least average fertility. Turf-forming wheat grasses—that is, those that reproduce largely by means of rootstocks—usually occupy the drier hillsides and exposed flats; but where slightly more than average moisture prevails during the growing season, the turfed species disappear and the taller and deeper-rooted wheat grasses of the bunched habit of growth become conspicuous.

Owing to the variation in the rate of soil formation and in moisture conditions, intensity of grazing, and other factors, the wheat-grass subclimax is often patchy, and is frequently temporarily replaced by rather distinct consociations of the lower successional stages.

Like most drought-resistant grasses, the wheat grasses thrive best in full sunlight. Accordingly, they are inconspicuous or entirely lacking where the herbaceous type meets the true fir-aspen cover in the lower reaches of the subalpine zone and, of course, in the dense spruce-fir cover of the higher elevations of the subalpine type.

Turfed and bunched wheat grasses are seldom associated, owing chiefly to the difference in the character of their root systems and the difference in the distribution of the moisture content of the soils which they occupy (Pl. II). Small wheat grass (*Agropyron dasystachyum*) is the most common and typical of the turfed species (Pl. II). Slender wheat grass (*A. tenerum*) and blue bunch wheat grass (*A. spicatum*) are the most conspicuous species of the bunched habit of growth, violet wheat grass (*Agropyron violaceum*) being next in order of abundance. Small wheat grass occurs on the drier hillsides, exposed flats, and on ridges where the soil is in a relatively high state of productivity; while slender wheat grass and blue bunch wheat grass, which are commonly associated, are largely confined to areas rather too moist for the successful development of small wheat grass, but not sufficiently moist for plants appreciably less drought-resistant than the wheat grasses. Thus, the well-drained areas subject to the full play of the high winds peculiar to the elevated summer range are characteristically occupied by turfed species; while habitats which are reasonably well protected from the wind and devoid of barriers which tend to diminish the reception of the normal rainfall are occupied by bunched wheat grasses.

A TYPICAL EARLY-WEED-STAGE COVER OF WHICH DOUGLAS KNOTWEED CONSTITUTES THE DOMINANT FORM OF VEGETATION. RELICTS OF BLUE FOXGLOVE ARE INCLUDED IN THE QUADRAT.



IN THE FOREGROUND A FULLY ESTABLISHED COVER; IN THE BACKGROUND A YOUNG SCATTERED STAND OF SMALL WHEAT GRASS (AGROPYRON DASYSTACHYUM).

The stand is so dense and the soil, below a foot or so in depth, so dry that deep-rooted species, like the bunch wheat grasses, are short-lived and often entirely lacking. Elevation 10,000 feet, Manti National Forest.

The rather strict line of demarcation in the habitat requirements of the two forms may be explained in two ways—(1) by the difference in the distribution of the available moisture of the soil and (2) by the depth to which the roots of the two grass forms extend.

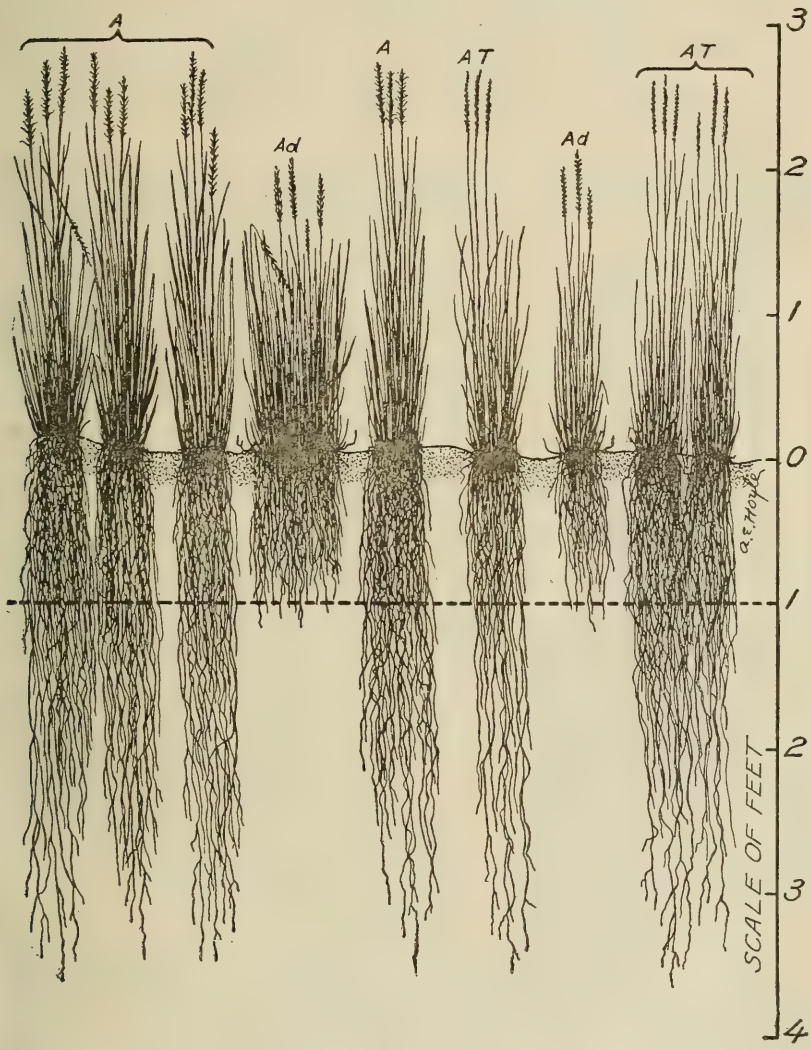


FIG. 2.—Relative height and character of root system of typical wheat grasses of the bunched and of the turfed habit of growth. *A*, Blue bunch wheat grass (*Agropyron spicatum*): *Ad*, Small wheat grass (*Agropyron dasystachyum*); *AT*, Slender wheat grass (*Agropyron tenerum*).

By far the greater portion of the absorbing surface of small wheat grass is confined to the upper 8 inches of soil, the average maximum depth of individual roots not exceeding about 15 inches (fig. 2). Because of the densely matted sod on areas where small wheat grass

has become well established the percolation of moisture is exceedingly slow; and, except after prolonged and heavy rainstorms, a surprisingly small proportion of the moisture passes beyond the densely matted soil stratum. Accordingly, the difficulty which other species encounter in gaining a foothold and their practical failure to compete successfully with the grass for the moisture essential to their proper development and perpetuation account chiefly for the characteristically pure stand of small wheat grass where its development is undisturbed.

The roots of the bunched species, slender wheat grass and blue bunch wheat grass (fig. 2), extend approximately 3½ times as deep into the soil as those of the small wheat grass, the average maximum depth being about 40 inches. Hence a large proportion of the root-absorbing surface of the bunch grasses is well below the average maximum depth of that of the turfed species. There is no appreciable difference in the root characteristics of the two bunch grasses under consideration. The distance between the bunches varies from a few inches to several feet, depending upon the moisture and other physical conditions. However, regardless of the distance between the bunches, provided the type is fully developed, there is relatively little difference in the character, density, and luxuriance of the other species which inhabit the intervening space, the normal stand of which is usually sparse.

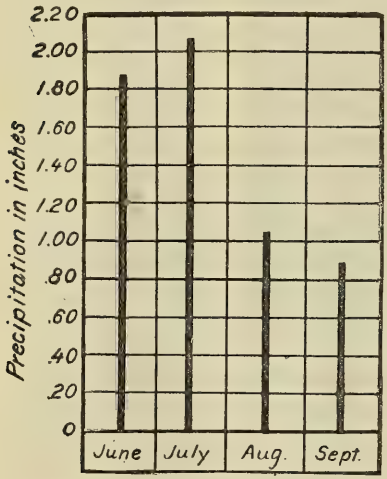


FIG. 3.—Average monthly precipitation in the wheat-grass formation during the growing season, 1914–1917, inclusive.

CONDITIONS OF GROWTH AND REPRODUCTION.

While the wheat grasses thrive under a considerable range of conditions, their optimum development is reached only where the soil is reasonably well decomposed and in a fairly high state of productivity and where sufficient moisture is available to supply vigorous plants during the first half of the growing season.

In the area under observation there is usually ample precipitation early in the spring of the year to saturate the soil (see Table 1 and fig. 3). Occasionally, however, the rainfall in June and in the first half of July is so light that the soil contains insufficient moisture for the promotion of vigorous growth.[1]

[1] Growth in the subalpine zone begins about the last week of June.

TABLE 1.—*Precipitation in the heart of the wheat-grass formation, 10,000 feet elevation, Manti National Forest, 1914–1917, inclusive.*

Year.	June.	July.	Aug.	Sept.
	Inches.	*Inches.*	*Inches.*	*Inches.*
1914	0.35	0.97	1.54	1.23
1915	2.12	1.84	.30	1.67
1916	.18	1.77	1.81	.39
1917	4.78	3.73	.50	.30
Average	1.86	2.08	1.04	.90

The average precipitation for the month as well as for the season varies widely. The greatest variation since 1914 in rainfall in June was 4.6 inches, the maximum being 4.78 inches in 1917, and the minimum 0.18 inch in 1916. In July the variation was 2.76 inches, the maximum being 3.73 inches in 1917 and the minimum 0.97 inch in 1914. Nearly 40 per cent of the 0.18 inch of precipitation recorded in June, 1916, fell during the first half of the month, while nearly 68 per cent of the 0.97 of an inch recorded in July, 1914, fell after July 20. Since only 0.35 of an inch of rain was recorded in June, 1914, the soil was far below the average in water content. Observations indicated that the unquestionable slowing down of growth noted after the first week in July, 1914, was due to an inadequate water supply.

FIG. 4.—Small wheat grass (*Agropyron dasystachyum*).

Owing to the exceptionally low water requirements for the survival of both the bunched and the turfed species of wheat grass, prolonged periods of soil desiccation, covering critical periods of one or more seasons, seem to have little effect on well-established plants other than to decrease temporarily the aerial growth and the reproduction. However, young stands of turfed species usually suffer appreciably less injury from soil desiccation than stands of bunch grass of similar age. This is accounted for by the fact that reproduction in the case of the turfed species is largely by extensive rootstocks which have little or no tendency to shoot out until the plant is per-

manently established and in vigorous condition (fig. 4). True bunch grasses, on the other hand, reproduce entirely from seed, two to three years being required to establish fully a seedling plant. Thus, while a shoot originating from the rootstock of a turf-forming species is largely nourished through the medium of the deep-rooted parent plant, the establishment of a bunch-grass seedling is dependent upon its own development for moisture and nutriment. Accordingly, turfed wheat grasses gain dominion over the soil in the drier situations where their rate of occupation may from time to time be more or less seriously interrupted through drought, but where the well-established plants are seldom killed. In such habitats the bunch grasses are usually killed out in the seedling stage, or the established plants, in competition for water, are crowded out by the shallow-rooted turfed species. On the other hand, habitats which receive considerable precipitation and are characterized by soils which permit of ready percolation of water are capable of supporting the deep-rooted plants. Such habitats are seldom if ever congenial to the domination, or indeed the conspicuous presence, of the turfed wheat grasses.

SOIL WATER CONTENT.

A comparison of the soil moisture conditions on a typical turfed (small wheat grass) area and on a typical bunch grass (blue bunch wheat grass) area in close proximity to each other may be made by observing the graphs in figure 5.

Section A of the graph, representing the moisture conditions of the soil supporting a typical stand of small wheat grass during the growing season of 1915, shows a rather sharp decline in the moisture content in the three soil strata studied (0–6, 6–12, and 12–24 inch depths) from July 1, which marks the beginning of vigorous spring growth, to September 20, the end of the growing period. On July 1 the highest per cent of moisture was recorded in the 0–6 inch layer of soil, 11.8 per cent of the water content being available for the use of the plant. In the 6–12 inch layer of soil for the same period there was approximately 1 per cent less moisture than in the upper layer, while in the 12–24 inch depth there was 4 per cent less. During the second period, however, there was a sharp decline in the moisture of the surface layer, and during the third period a rather striking increase. In the 6–12 and 12–24 inch depths for the same periods the decline was gradual, which is typical of all subsequent periods at the two lower depths.

The most significant facts brought out in section A, however, are (1) the rather striking fluctuations in the water content in the 0–6 inch layer, and (2) the fact that the water content in the 0–6 inch depth of soil is reduced to a point at which it becomes unavailable

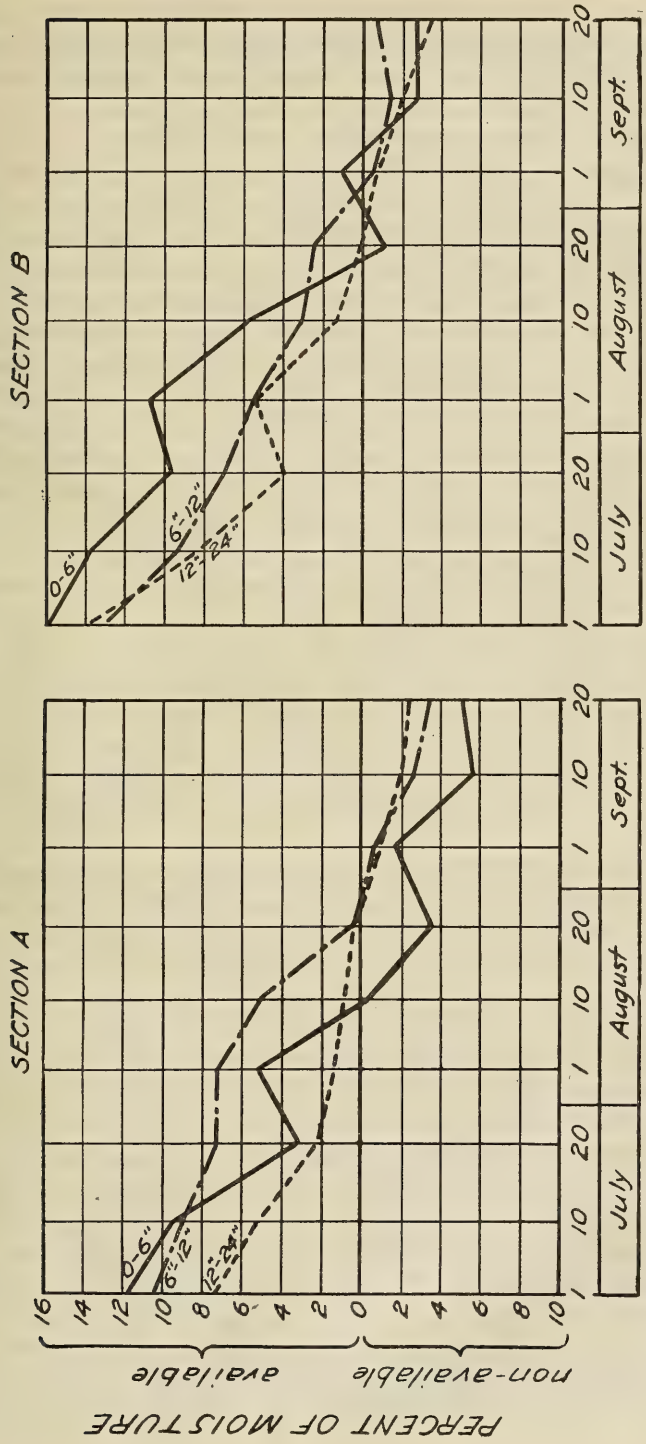


FIG. 5.—(*A*) Average available and nonavailable soil moisture on a typical area fully occupied by small wheat grass (*Agropyron dasystachyum*), 1915. (*B*) Average available and nonavailable moisture on area occupied by a normal stand of blue bunch wheat grass (*Agropyron spicatum*), 1915.

to the plant 10 days earlier than in the two lower depths. During the driest period of the season, usually beginning about August 10 in the 0–6 inch depth, and about August 20 in the deeper layers, the main root system often occupies soil whose moisture content is well below that at which vegetation can absorb moisture. The fluctuations in the water content observed to occur in the superficial soil layer and the practical absence of such fluctuations in the deeper layers, notably the 12–24 inch depth, are chiefly accounted for by the fact that the supply of moisture in the upper stratum, in which the greater portion of the feeding roots are located, is used up by the vegetation at a relatively rapid rate. Since the upper soil layer is especially rich in organic matter, hence is capable of absorbing a very high percentage of water (45–65 per cent) as it percolates through the matlike layer, the rapid desiccation of the superficial soil is all the more significant. Thus it will be seen that the reduction in the water content in the superficial layer to a point below the amount necessary to make it available to the use of the plant was reached as early as August 10, so that any water absorbed by the plant later in the season had to be obtained at a depth greater than 6 inches. The two lower depths of soil, it will be noted, likewise became desiccated after August 20. Therefore at the end of the growing season the 0–6 inch layer of soil was 5 per cent below the point of available moisture, while the 6–12 and 12–24 inch layers were 3.3 and 2.1 per cent below, respectively. In general the growth and seed production are completed in the case of small wheat grass by August 15, when the herbage dries up and remains dormant until the spring.

Section B of figure 5 represents the moisture conditions on a blue bunch grass area during the growing season 1915, the soil samples from which the data were obtained being taken simultaneously with those represented in section A. Comparing first the general position of the respective curves, it will be seen that the water content was greater on the blue bunch grass area than on the turfed wheat grass area in each period, with the exception of September 10 to 20 in the 12–24 inch depth, prior to which growth had been arrested. In contrast with the condition on the turfed area, the moisture content in the 0–6 inch layer on the bunch grass type was appreciably in excess of that at greater depths during the first four periods. In the fifth period the moisture content decreased rapidly in the upper soil layer and dropped below that recorded at the two lower depths; but in the sixth period, as the result of a fairly heavy rainstorm, the moisture content again exceeded that in the lower soil layers. Thus, instead of the 6–12 inch soil depth containing the highest percentage of moisture during the most active period of growth, as in the turfed wheat grass type, the 0–6 inch layer contained the maximum amount.

As in the case of the turfed area, the moisture content on the bunch-grass area became unavailable, except for a few days in the superficial layer between August 20 and September 1.

THE EFFECT OF DISTURBING FACTORS.

The opening up by excessive grazing or otherwise of a well-established stand of small wheat grass, as well as of congeneric turfed species, is congenial to the immediate establishment of a rather scattered growth of other plants, both deep-rooted and shallow-rooted, provided, of course, that seed is available and growth is not seriously hampered. Where the fertility of the soil is not appreciably changed as a result of the destruction of the wheat-grass turf, several shallow-rooted species and a few aggressive deep-rooted plants soon make their appearance. Obviously, the shallow-rooted species, as a result of both aerial and subterranean competition, sooner or later yield to the invasion of the more permanent and luxuriant deep-rooted plants.

Among the deeper-rooted perennials which gain a foothold early in the destruction of the matlike growth of wheat grasses where the fertility of the soil is not appreciably decreased, yellow brush (*Chrysothamnus lanceolatus*) is the most characteristic. Of the perennial grasses, small mountain porcupine grass (*Stipa minor*) is the most characteristic. These two plants are among the first of the deep-rooted perennials to signify the waning of the wheat-grass cover. Where the wheat-grass type is relatively young it often supports an occasional plant of yellow brush which may struggle along for several years in competition for water with the superficial roots of the wheat grass.[1] In due time the yellow brush, approximately 90 per cent of whose root-absorbing surface is below that of the wheat grass, gives away; but when the stand is opened up any remaining straggling yellow-brush specimens quickly regain their luxuriance of growth. (Fig. 6.)

Section A of figure 6 portrays a relatively young stand of small wheat grass where yellow brush was conspicuous prior to the establishment of the wheat grass subclimax. Section B shows the incoming of small wheat grass from seed and the unhampered growth of yellow brush. Should the wheat-grass subclimax (section A) again be destroyed, or the stand sufficiently opened up to favor the percolation of a considerable portion of the rainfall to a depth corresponding to the location of the main feeding roots of the yellow brush, the surviving specimens of the latter would immediately show a remarkable response in growth. An increasing abundance of yel-

[1] While yellow brush is persistent in competition with other species, it is not believed to be a very long-lived species. Numerous stem examinations have shown that it seldom attains an age of much more than 10 years. A single specimen with 12 annual rings was found.

low brush, as well as of other plants, especially deep-rooted species, indicates, therefore, a retrogressive succession in the wheat-grass type.

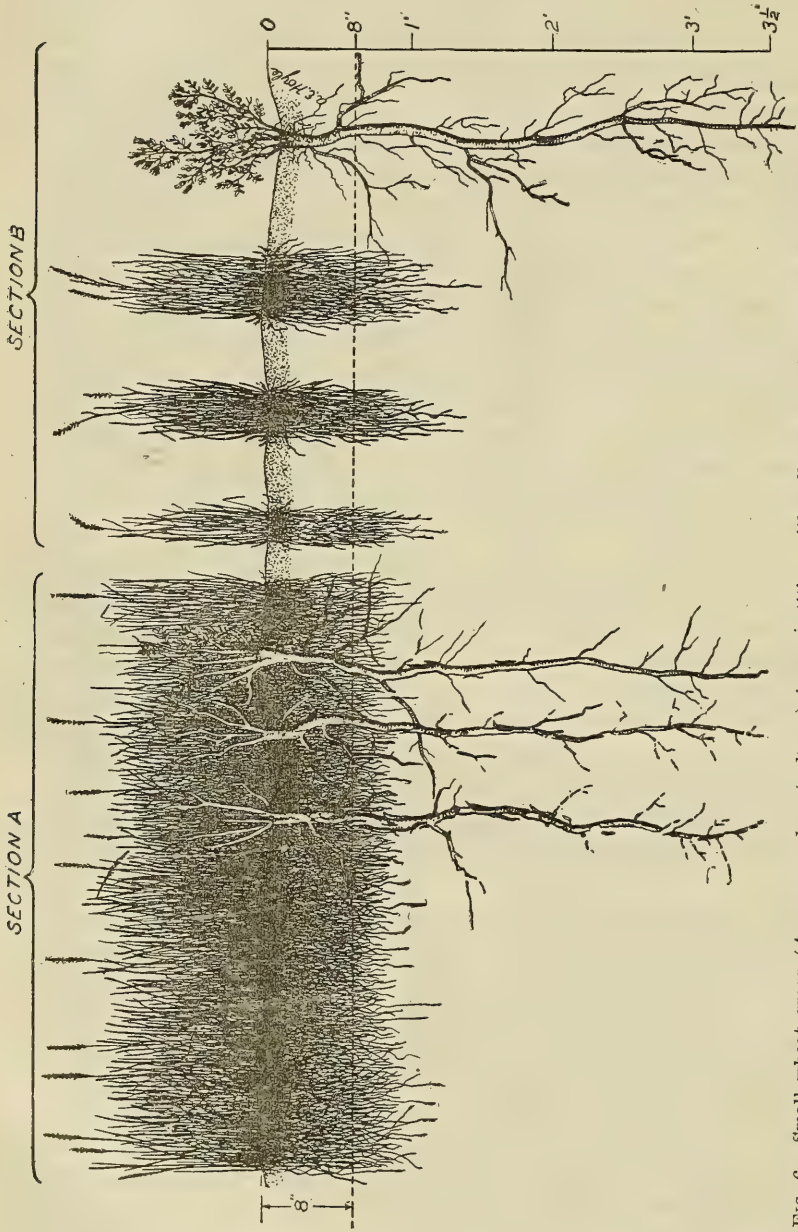


FIG. 6.—Small wheat grass (*Agropyron dasystachyum*) in competition with yellow brush (*Chrysothamnus lanceolatus*), showing (section A) area where yellow brush occupied the soil when grass sod was opened up as a result of overgrazing and where the wheat grass subclimax was subsequently reestablished the yellow brush killed or merely straggling along; (section B) where (1) yellow brush is growing luxuriantly without competition with other plants, and (2) where a greater depth of the root development occurs in the case of specimens of wheat grass as compared with the sodded stand.

Section B of figure 6, in addition to showing that the roots of a healthy specimen of yellow brush may feed at a depth in excess of 3½ feet, emphasizes the interesting fact that small wheat grass

develops a somewhat deeper root system when the specimens are isolated than when the plants grow in a well-established sod. This increased development is doubtless accounted for by the fact that the water content of the soil immediately below the deeper roots of the isolated bunched wheat grasses is appreciably higher than in the soil below the deeper roots of the sodded stand. Since all stands of small wheat grass become matted when permitted to develop normally in well-disintegrated soils, it is evident that the increased development in depth of the roots of isolated specimens, as compared with that of the turfed plants, is purely temporary, and probably of little or no economic significance.[1]

In contrast with the turfed wheat-grass type, the conditions that obtain in a normal, fully developed bunch wheat-grass type are such as to permit the presence of other plants of both deep-rooted and shallow-rooted species (fig. 7). The shallow-rooted species, such as mountain squirrel tail (*Hordeum nodosum*), single-flowered helianthella (*Helianthella uniflora*), and others, feed chiefly in the upper foot of soil, but the density of the cover as a whole is never such as to prevent a comparatively rapid percolation of water to a depth of several feet. In general, a large part of the rainfall is absorbed on lands where bunch wheat grass is fully developed, so that serious erosion seldom occurs so long as the natural cover remains unimpaired. Because of the high power of absorption of the soil and the relatively high percentage of available moisture in the lower soil depths, a few deep-rooted species, like wild bean or alpine lupine (*Lupinus alpestris*), yellow brush, and the like, as well as certain surface-feeding plants, like single-flowered helianthella (*Helianthella uniflora*), mountain squirrel tail (*Hordeum nodosum*), and blue foxglove (*Pentstemon procerus*), occupy the space between the grass bunches where the spacing is fairly wide and the intervening soil not fully occupied by grass roots. Therefore, where the bunch wheat grass stand is opened up by grazing or by other adverse factors, a good balance both of deep and of shallow rooted species, chiefly other than grasses, follows, one set of species predominating at one time and another set at another time. Accordingly, a reasonable state of equilibrium in the vegetation occupying the space between the bunch-grass tufts exists only when the maximum density of the bunch-grass stand has been reached and has become stabilized. This stabilization of the rather transitory type of vegetation may be accounted for by the comparative equality in the utilization of the available water content of the soil by the wheat grasses.

[1] Cannon, W. A. (Plant World, vol. 16, No. 12: 323–241, 1913), found that the root development of desert plants varies widely in soils of different texture and depth. These variations were observed to hold regardless of whether the plant was grown under natural conditions, in garden soils, or in artificial cultures.

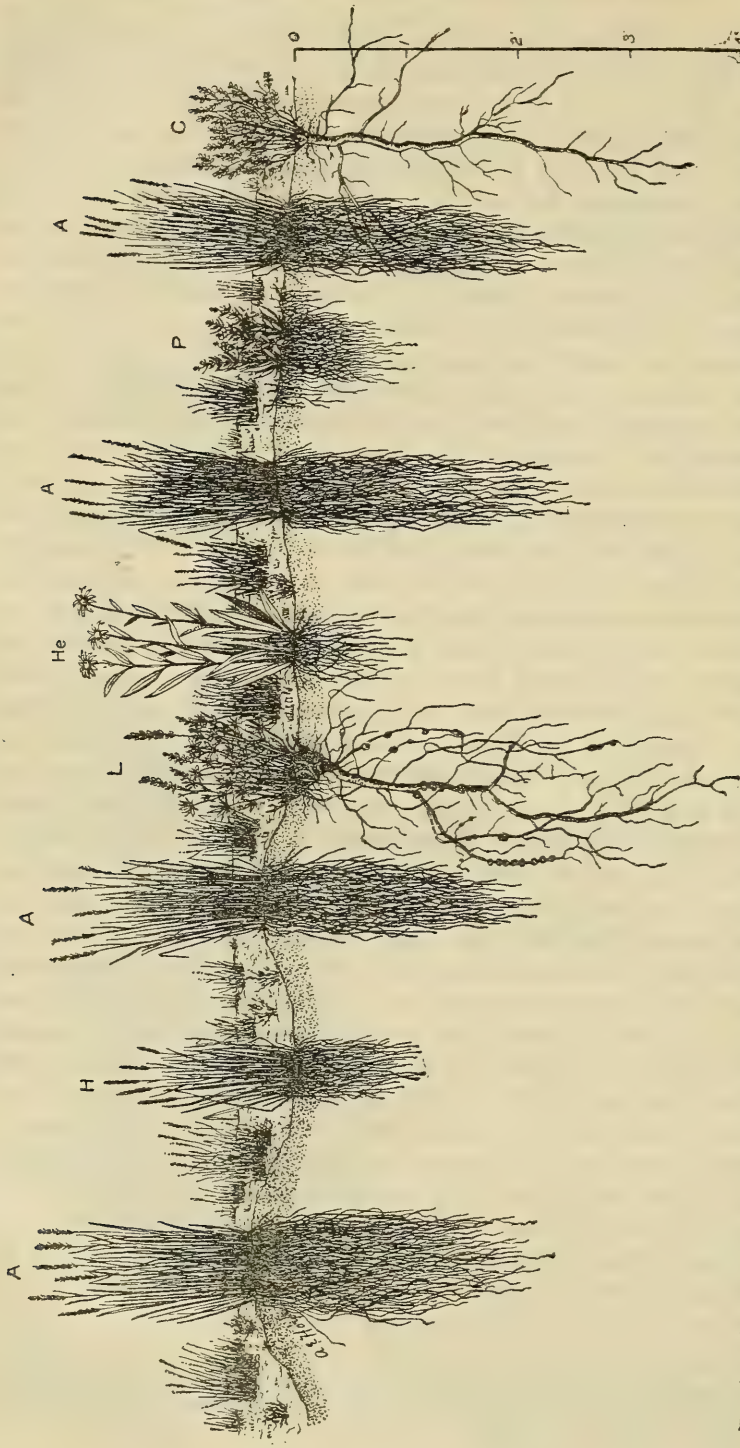


FIG. 7.—Slender wheat-grass type, showing characteristic association of deep and shallow rooted vegetation where the grass stand has been somewhat thinned out as a result of heavy grazing. *A*, Slender wheat grass (*Agropyron tenerum*); *C*, yellow brush (*Chrysothamnus lanceolatus*); *H*, mountain squirrel tail (*Hordeum nodosum*); *He*, single-flowered helianthella (*Helianthella uniflora*); *L*, wild bean (*Lupinus alpestris*); *P*, blue foxglove (*Pentstemon procerus*).

PALATABILITY.

The wheat grasses of the high mountain range afford a large amount of first-class forage for all classes of stock. However, the herbage of the wheat grasses as a whole, especially after the plants have reached maturity, is of only average palatability compared with the finer-leaved genera of grasses, such as the blue grasses (*Poa*) and fescues (*Festuca*) of a lower successional stage. When green and succulent the leafage is cropped rather closely by cattle, sheep, and horses; but as the plants reach full growth the leafage of some of the species becomes somewhat harsh. At that stage cattle and horses devour the herbage less closely than when the plants are young, leaving the rather coarse seed stalks practically untouched. Sheep, on the other hand, crop only a relatively small proportion of the herbage of the maturing or matured plant, but in general eagerly consume the seed heads of the awnless or slightly awned species.

Like the majority of the congeneric species, small wheat grass when green and tender is eaten closely by all classes of stock. As the plant approaches maturity, however, the leafage becomes rough on the upper side, and only cattle and horses graze upon it to an appreciable extent. The palatability of the wheat grasses throughout the season being taken into account, small wheat grass affords the least feed of any under discussion in proportion to the amount of dry matter produced.

Of the bunch wheat grasses, slender wheat grass and violet wheat grass compare favorably as to palatability, both being grazed closely by all classes of stock. Blue bunch wheat grass is only slightly less palatable. All of these species are grazed with unusual eagerness by cattle, sheep, and horses early in the season. Toward the approach of maturity the herbage, especially of blue bunch wheat grass, is consumed much less closely than early in the summer, and the seed stalks of all species are left practically untouched. With the exception of blue bunch wheat grass, the spike of which is conspicuously awned, the seed heads are grazed with avidity and with good results to stock.

FORAGE PRODUCTION.

The largest amount of dry matter, exclusive of the unpalatable flower stalks, is produced by the small wheat-grass type. This type, when permitted to develop normally, usually occupies the entire soil surface. Owing to its relatively low palatability after about August 10, however, small wheat grass affords no more forage, season for season, than good stands of the bunched wheat grasses. Also on account of the lack of forage variety due to the practical exclusion of other plants, the small wheat-grass areas are not so well adapted to the grazing of sheep as are the bunch wheat-grass areas.

Of the bunch wheat grasses, slender wheat grass and blue bunch wheat grass are about equal in the amount of dry matter produced per unit of area, while violet wheat grass, occurring as it usually does in rather scattered stands, seldom produces as much forage as the other two species. Owing to the slightly higher palatability of slender wheat grass as compared with blue bunch wheat grass, the former supports slightly more stock per acre than the latter.

The bunch wheat-grass areas, because of the class of plants which they support, are better suited to the grazing of sheep than are the turfed wheat-grass areas. The latter, on the other hand, are especially well adapted to the grazing of cattle and horses; for to make good gain these animals require less variety than sheep, and they consume, proportionately, a smaller amount of weeds than sheep.

In general the most efficient range for cattle and horses is one upon which the palatable subclimax grass species have been preserved. In the case of sheep the range which will afford the largest percentage of first-class feed and at the same time prove the most efficient from the standpoint of pounds of gain for the season is one upon which the grass stand has been sufficiently opened up to permit of a good admixture of grass, weeds, and even browse. The fact that sheep prefer a greater forage variety than is found on ranges where wheat grasses predominate does not imply that the climax grass type should be grazed destructively with a view of fostering the establishment of a large variety of more or less transitory weed species. As a rule by far the biggest returns will be obtained from the lands by grazing the class of stock upon them which will most fully utilize the forage crop. Sooner or later the original stand of palatable plants may give way to other species, a condition which may fully justify the grazing of both cattle and sheep.

SUMMARY OF THE WHEAT-GRASS CONSOCIATION.

Wheat grasses constitute the potential subclimax type in the high mountain summer range of the Wasatch Mountains. That is to say, lands occupied by a maximum cover of wheat grass support the highest and most stable type that the soil is capable of supporting. Accordingly, this type, when in a maximum state of productivity, affords most reliable evidence of the fact that the range has not been overgrazed, at least within a reasonable length of time.

The wheat-grass type is composed of two general growth forms; namely, turf-forming and bunch-forming species. The turfed type is characterized by roots which feed in the upper few inches of soil, which tends to bind the soil firmly. The bunch type is characterized by deeply penetrating roots, and since the space between the bunches varies from a few inches to several feet, the stand is rather open.

Owing to the small amount of precipitation that penetrates beyond the shallow matlike surface of the turfed wheat-grass type, bunch wheat grasses and other deep-rooted species are seldom associated with a fully established stand of the sodded wheat-grass cover. The bunch wheat-grass type, on the other hand, supports a considerable variety of weeds and other plants, both of deep and of shallow rooted characteristics.

Regardless of the growth form of the wheat-grass cover, yellow brush (*Chrysothamnus lanceolatus*) is the most characteristic forerunner of other aggressive perennial plants which gain a foothold as the wheat grasses are killed out by overgrazing or other adverse factors. Small mountain porcupine grass is commonly associated with the yellow brush. As the turfed wheat grass is reestablished, yellow brush and porcupine grass are entirely replaced. In the revegetation of the bunch wheat-grass cover, both yellow brush and porcupine grass are rather persistent, as the moisture conditions remain comparatively favorable to the invading species until the original grass cover is fully reestablished. Eventually, however, most of the yellow brush and porcupine grass plants are crowded out. Thus the invasion and conspicuous establishment of yellow brush and porcupine grass on the wheat-grass type generally indicate clearly that one or more unfavorable factors are at play, which, if permitted to continue, may result in the destruction of the wheat-grass type. On the other hand, the waning of the indicator plants, due to competition with the wheat grass, affords reliable evidence of the reestablishment of the wheat-grass type.

There is relatively little difference in the number of cattle and horses that the turfed and the bunched wheat-grass areas are capable of supporting in good condition. Sheep, on the other hand, make better returns on typical bunch wheat-grass lands than on the turfed areas because of the greater variety of forage which the bunch-grass type usually supports. In spite of this fact, however, no attempt should be made to overgraze either grass cover with the idea of improving the lands for the grazing of sheep. To do so will seriously decrease the forage production of the lands for the grazing of cattle and horses. After a few years of full utilization of the wheat-grass consociation by cattle and horses a large variety of plants usually appears. This natural replacement of the palatable grasses by plants successionally lower in the scale of development will improve the lands for the grazing of sheep and thus bring about a condition which will justify cropping by all classes of stock in proper proportions. Where common use of a wheat-grass range is resorted to, after the cover has partly reverted to the weed stage, the cattle grazed should be reduced in number to the point where the remaining vegetation palatable to this class of stock will be safe from further destruction.

If this is not done, the retrogression of the vegetation to a pure second-weed stage, or, indeed, to the first-weed stage, is inevitable.

THE PORCUPINE-GRASS-YELLOW-BRUSH CONSOCIATION.

As a result of the serious overgrazing in the Wasatch Mountains prior to the inclusion of the lands in the Wasatch Forest in 1905, the wheat-grass consociation was much injured in many localities. Where the fertility of the soil was not appreciably impaired after the destruction of the subclimax grass cover, the wheat grasses soon reestablish themselves; but where appreciable erosion took place or where a considerable proportion of the soluble soil nutrients was leached out, the wheat-grass species failed to reoccupy the lands. On the seriously impoverished soils, only a sparse stand of short-lived plants at first gained a foothold; but on areas where the fertility and the water-holding capacity of the soil were only slightly impaired, grasses, notably small mountain porcupine grass (*Stipa minor*) (fig. 8), and its ever-present associate, yellow brush (*Chrysothamnus lanceolatus*), predominated. Where the soil was more seriously depleted, blue grasses, fescues, brome grasses, and others were invariably associated with porcupine grass and yellow brush.

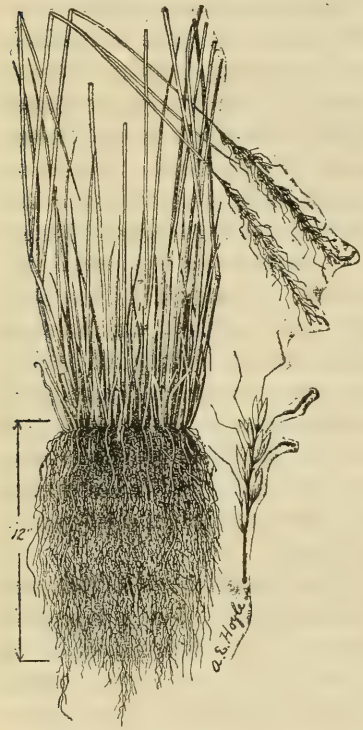


FIG. 8.—The dominant species of the porcupine-grass-yellow-brush consociation.

After the destruction of the wheat-grass consociation by overgrazing, a large proportion of the entire cover was then either of the early or late weed stage; but as a result of correcting the destructive factor of overstocking, the porcupine-grass-yellow-brush type now constitutes the most extensive consociation of relatively high-carrying capacity in the high mountain region.

Small mountain porcupine grass and the local congeneric species grow as bunch grass, and the intervening space is occupied by other grasses and nongrasslike plants. Where the soil has undergone only slight change physically and chemically as compared with its condition when occupied by the wheat-grass cover, the stand of small mountain porcupine grass and yellow brush is full, and the stand

of secondary species is relatively sparse. On the other hand, when the soil has been more seriously depleted, these two species merely occupy the chief place, many other species, especially grasses, being associated with them (fig. 9). Much of the acreage which had become so badly depleted in 1905 as to support only a scattered stand of the most drought-resistant and short-lived vegetation, has now been revegetated to the point of supporting a good, and in some instances a maximum, cover of porcupine grass and yellow brush, with the scattered admixture of other species, especially grasses high in the cycle of development. On areas where the vegetation has for one reason or another met with reversals from time to time, porcupine grass and yellow brush are much less conspicuous, though they constitute the predominating species. At this stage in the revegetation only the grasses that are characteristic of early successions are associated with the porcupine grass and yellow brush.

In general, the secondary species of the porcupine-grass-yellow-brush consociation are numerous and of much importance economically.[1] Among the more common grasses may be mentioned Nevada blue grass (*Poa nevadensis*), Malpais blue grass (*P. scabrella*), little blue grass (*P. sandbergii*), spiked fescue (*Festuca confinis*), western fescue (*F. occidentalis*), mountain June grass (*Koeleria cristata*), spiked trisetum (*Trisetum spicatum*), mountain brome grass (*Bromus marginatus*), Porter's brome grass (*B. porteri*), and frequently a scattered stand of wheat grasses, of which Scribner's wheat grass (*Agropyron scribneri*) is somewhat conspicuous. Typical examples of the more important grasses are shown in figure 10. Among the more common herbs other than grasses (aside from the ever-present yellow brush) are yarrow (*Achillea lanulosa*), sweet sage (*Artemisia discolor*), several species of loco, notably *Astragalus decumbens* and *A. tenellus*, single-flowered helianthella (*Helianthella uniflora*) geum (*Geum oregonense*), wild bean (*Lupinus alpestris*), and blue foxglove (*Pentstemon procerus*). Upon closer view one normally finds a very scattered stand of James' chickweed (*Alsine jamesiana*), scarlet gilia (*Gilia pulchella*), gymnolomia (*Gymnolomia multiflora*), pingue or rubberweed (*Hymenoxys floribunda*), and others. In addition there are a number of inconspicuous annuals.

These numerous secondary species (fig. 9) vary widely as to the distribution of their chief feeding roots. All the more important grasses, with the exception of the brome grasses, obtain their moisture supply from practically the same soil stratum as does porcupine grass. The brome grasses, the locos, and wild bean, on the other hand, extend their roots to approximately the same depth as yellow brush. Accordingly, single-flowered helianthella, geum gymnolomia,

[1] See also Pound, Roscoe, and Clements, Frederic F., The Phytography of Nebraska, 381–383, 1900.

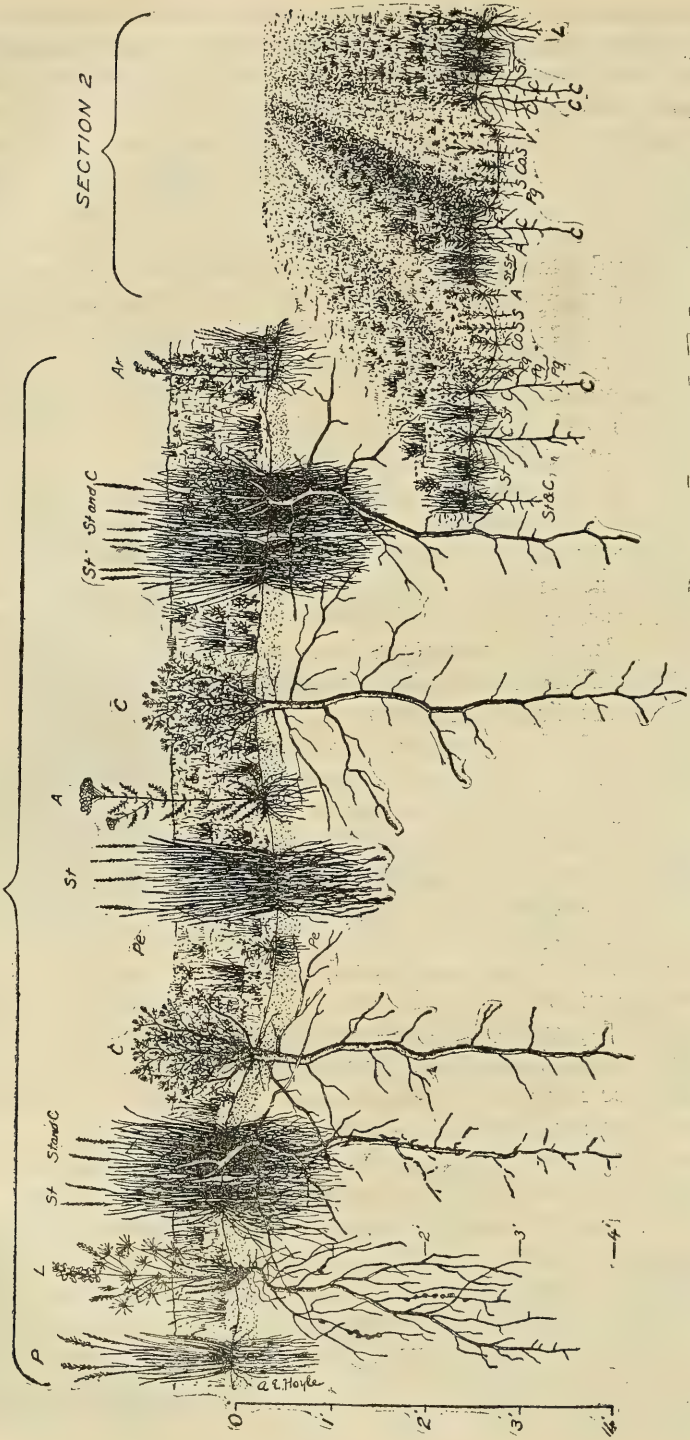


FIG. 9.—Porcupine-grass-yellow-brush consociation—showing (section 1) character of root systems of the dominant species and of the species characteristically associated with porcupine grass and yellow brush, and (section 2) the character of the vegetation on old road through a stand of porcupine grass and yellow brush abandoned for five years (1913–1917). *A*, Yarrow (*Achillea lanulosa*); *Ar*, sweet sage (*Artemisia discolor*); *C*, yellow brush (*Chrysothamnus lanceolatus*); *Co*, slender-leaved collomia (*Collomia linearis*); *E*, erigeron (*Erigeron macranthus*); *L*, wild bean *Lupinus alpestris*); *P*, Nevada blue grass (*Poa nevadensis*); *Pe*, blue foxglove (*Pentstemon procerus*); *Pg*, knotweed (*Polygonum aviculare*); *S*, tansy mustard (*Sophia incisa*); *St*, small mountain porcupine grass (*Stipa minor*); *V*, tongue-leaved violet (*Viola linguaefolia*).

and rubberweed may be classed as intermediate in the elongation of their roots between small mountain porcupine grass on the one hand and yellow brush on the other. Yarrow, sweet sage, and blue foxglove, James' chickweed, scarlet gilia, and the annuals, being less deeply rooted than small mountain porcupine grass, may be classed

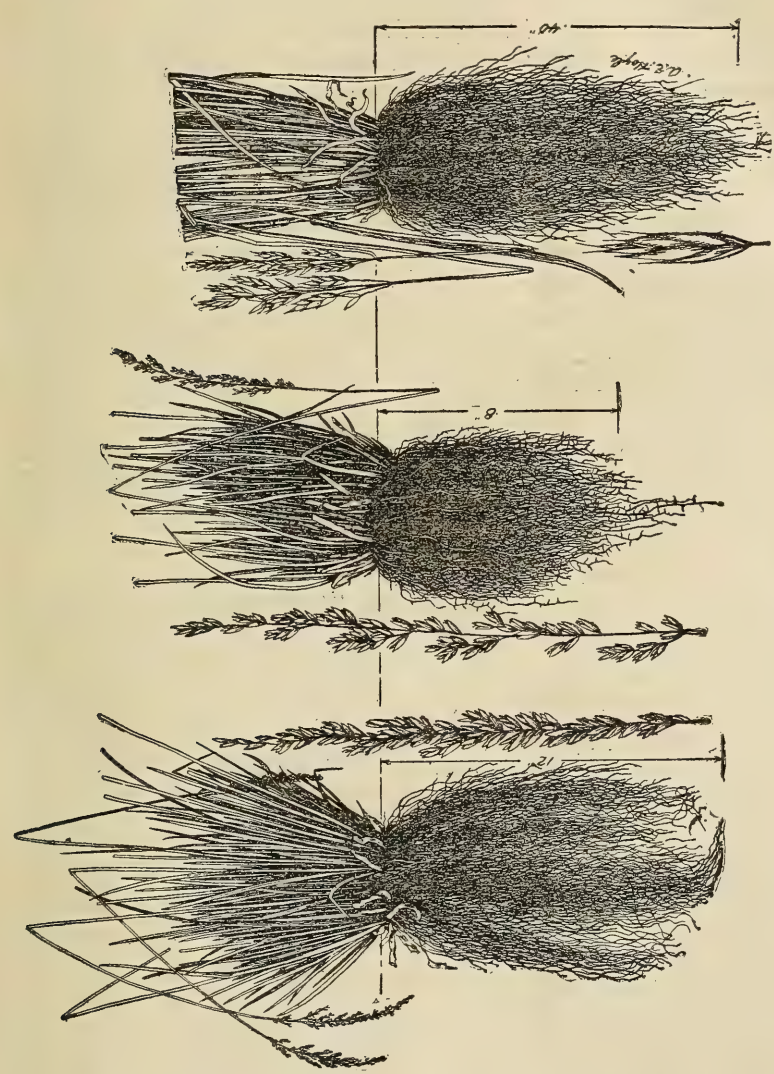


FIG. 10.—Characteristic grasses of the porcupine-grass-yellow-brush consociation.

as superficial feeders. This wide variation in the extension of the roots is accounted for, of course, by the uniformity in the distribution of the water in the soil from the surface to the extreme depth to which the roots extend. The roots of the numerous species constituting this consociation are so evenly distributed through the soil

from the surface to a depth of 3 feet or more that the substratum usually becomes desiccated from a few inches below the surface to the average depth of the longest roots at approximately the same time in the season.

CONDITIONS OF GROWTH AND REPRODUCTION.

Porcupine grass feeds in approximately the same soil stratum (fig. 9) as turfed wheat grass, the average maximum depth of the roots being about one-third that of the bunched wheat grass. Yellow brush, on the other hand, extends its roots to about the same depth as the bunched wheat grasses. Porcupine grass and yellow brush therefore enter into serious competition for water only where the porcupine-grass tufts occur so densely as to prevent ready percolation of water to the lower depth of soil, a condition which occurs somewhat commonly only on the older and fully stocked areas. Generally, the porcupine-grass-yellow-brush consociation is more open, at least below ground, than the bunched wheat-grass lands (compare figs. 7 and 9); hence it is characterized by a more rapid percolation of water through the soil than occurs in the bunched wheat-grass cover. For this reason there is less variation in the distribution of the water from the surface downward on a porcupine-grass-yellow-brush area than on an area supporting a normal stand of bunched wheat grass. The depth to which the precipitation penetrates on the sodded wheat-grass area is extremely shallow as compared with the depth of penetration on a bunched wheat-grass area or on a porcupine-grass-yellow-brush area. Therefore, it is clear that so far as the available soil water supply is concerned, conditions are far more favorable for the establishment of species of variable length and character of root system on the porcupine-grass-yellow-brush type than on the turfed wheat-grass areas. Likewise, owing to the more open stand and the shallow feeding roots of porcupine grass, the soil water content, between 1 and 4 feet in depth, is available to a greater variety of plants other than grasses on this consociation than on a fully developed area of bunched wheat grass, the moisture supply for which must be obtained from the same soil depth as for the support of other deep-rooted plants.

While a relatively large proportion of the precipitation is absorbed on the porcupine-grass-yellow-brush consociation, this cover, as in the case of the wheat-grass type, never occupies soils that remain too moist for the promotion of vigorous growth. During unusually dry years, growth slows down markedly, a condition which results in the temporary disappearance of many of the secondary species. Small mountain porcupine grass and yellow brush, however, are persistent, though yellow brush yields more readily to the effects of soil desiccation than does its grass associate.

SOIL WATER CONTENT.

Specific measurements of the water content of the soil have brought out two interesting facts. First, the water-holding capacity in the upper foot of soil on a well-established stand of porcupine grass and yellow brush is less than on similar areas where the wheat-grass type is equally well established. The average of 15 soil samples obtained in 1915 of soils supporting a turfed cover of wheat grass was 11.2 per cent higher than the average of the same number of soil samples on the porcupine-grass-yellow-brush area previously occupied by turfed wheat grass. Soil samples taken on the same areas in 1916 and 1917, as in the preceding year, gave practically the same relative figures. Likewise, the same number of soil samples, representing the bunched wheat-grass cover showed an average of 4.6 per cent more moisture than that of the porcupine-grass-yellow-brush cover. Second, the average available water content of the soil when saturated was less on the porcupine-grass-yellow-brush areas than on the wheat-grass lands; and, as might be expected, the available water content was exhausted correspondingly earlier in the season. Therefore, on an average, growth is arrested somewhat earlier on fully stocked porcupine-grass-yellow-brush areas than on fully stocked areas of the wheat-grass type.

THE EFFECT OF DISTURBING FACTORS.

The most reliable indication of the presence of conditions adverse to the perpetuation and maintenance of the highest development of the porcupine-grass-yellow-brush consociation, including its less stable cover of secondary species, is the replacement of one or both of the dominant species by other aggressive plants, chiefly nongrass-like species. As shown in figure 9, there is normally present on the porcupine-grass-yellow-brush areas a more or less scattered stand of plants of the second-weed stage, of which yarrow (*Achillea lanulosa*), sweet sage (*Artemisia discolor*), and blue foxglove (*Pentstemon procerus*) are the most typical. These species are almost invariably among the first of the more permanent nongrasslike plants to increase in abundance as the porcupine grass and yellow brush are killed out. Because they reproduce almost entirely by vegetative means from long rootstocks, these nongrasslike plants probably increase more rapidly than any other perennial nongrasslike species. Accordingly, they may be declared the most reliable indicators of the presence of some factor, or combination of factors, adverse to the porcupine-grass and yellow-brush stand with its many desirable associated species. For a time the dead or dying porcupine-grass-yellow-brush cover is replaced by plants of the same species. As the unfavorable conditions continue their play, however, the

soil with its decreased moisture supply becomes unfavorable to the maintenance of the original plant cover, and reproduction, both by vegetative means and by seed, is greatly curtailed; but the conditions produced strongly favor the rapid invasion and establishment of the formerly suppressed blue foxglove, sweet sage, and yarrow, and these with certain other plants soon become established. The majority of these invading species feed in approximately the same soil stratum as small mountain porcupine grass—that is, chiefly in the upper foot or so of soil.

The safest indications pointing toward the maintenance or perhaps the progressive or higher development of the depleted and thinned porcupine-grass-yellow-brush consociation, is an increasing density and luxuriance of certain blue grasses and fescues, all of which are shallow-rooted, and a decreasing abundance or entire absence of the brome grasses and other deep-rooted species characteristic of earlier successional stages.[1] This gradual elimination of the deep-rooted species is, of course, accounted for by the fact that the available moisture supply in the lower soil depth decreases in somewhat the same proportion as on the wheat-grass areas. Among the blue grasses characteristically associated with the highest developed stands of the porcupine-grass-yellow-brush type, Nevada blue grass and little blue grass are the most conspicuous. In less abundance, but in approximately the same stage in the succession, occur Buckley's blue grass (*Poa buckleyana*), and Fendler's blue grass (*P. fendleriana*). Malpais blue grass, on the other hand, usually reaches its maximum abundance prior to the highest development of the porcupine-grass-yellow-brush cover. Like many of the perennial nongrasslike species, it has all but disappeared when the porcupine-grass and yellow-brush stand has attained its maximum density.[2]

When the porcupine-grass-yellow-brush consociation has prepared the way for the invasion and establishment of the wheat-grass type, porcupine grass is usually more abundant than yellow brush, and competition of a more or less serious character occurs between the porcupine-grass and the yellow-brush plants. As the bunches of porcupine grass increase in number and size, the rate and depth of the percolation of rainfall into the soil greatly decrease. This re-

[1] In general the brome grasses are relatively low in the cycle of succession. They usually precede the blue grasses, fescues, and porcupine grasses. Likewise, the blue grasses and fescues usually precede the porcupine grasses, though this varies somewhat with the species. Because of the exceptionally strong seed habits of porcupine grass and the fact that the seeds are self-planted, and a good stand of seedlings is therefore assured under favorable conditions of soil and moisture, a somewhat general belief prevails that porcupine grass may precede the brome grasses, the blue grasses, the fescues, and certain other grasses in the succession. Detailed quadrat data have proved this belief erroneous.

[2] The approach toward the highest development of the porcupine-grass-yellow-brush type can usually be recognized by the presence of at least a scattered cover of wheat grasses, of which violet wheat grass is usually the first to appear.

tention of the water supply in the upper layer of the soil in seasons of less than normal rainfall often causes somewhat serious desiccation in the lower soil layer, upon which yellow brush is largely dependent for water, and results in the death of many of these plants. Obviously, however, the desiccation of the lower soil layer is most serious immediately beneath the dense bunches of porcupine grass. As a result of the seed of porcupine grass finding ready lodgment and conditions especially favorable for germination immediately beneath the expanded branches of yellow brush, dense tufts of porcupine grass, as shown in figure 9, often develop around the yellow-brush plants. The established yellow-brush plant is killed in a season or two or possibly straggles along for a few seasons. Where the competition is not too severe some of the branches of the yellow brush die and most of the branchlets on the remaining branches are killed, thus greatly reducing the leaf surface as well as the loss of water from transpiration. This reduction in the leaf surface often permits yellow brush to hold its place with the porcupine grass for a considerable time. Naturally under such conditions yellow brush produces few flowers and practically no viable seed, so that physiologically its behavior is much the same as a plant that has been seriously weakened as a result of too frequent cropping.

PALATABILITY.

With its large variety of palatable plants and its relatively small percentage of waste range, the porcupine-grass-yellow-brush consociation probably furnishes as ideal a vegetative cover for all classes of grazing animals as the lands are capable of producing. Small mountain porcupine grass, of which the foliage is finer leaved and less harsh than that of the wheat grasses, is grazed with relish by all classes of stock throughout the foraging season. While vigorous growth ceases in most habitats during the first half of August, the herbage remains more or less green until well into September. When cured, the leafage of small mountain porcupine grass, like that of many other fine-leaved grasses, is cropped with relish by cattle and horses. Sheep take a fair proportion of the herbage after the plant has reached maturity, but the writer has never observed this class of stock to graze porcupine grass as closely as cattle and horses unless forced to subsist upon it.

The seed heads of porcupine grass, unlike those of the wheat grasses and many other grass species, are not particularly sought for by stock, especially when the plant is approaching maturity or after the seeds have ripened. In the first place, the seeds are rather small and do not attract stock. In the second place, the basal portion of the seed is sharp-pointed while the apex elongates into a rather

prominent awn, which, when the plant approaches maturity, becomes rather stiff and is objectionable to stock. This lack of palatability of the seed heads, however, in no way impairs the value of the herbage. The fact, however, that the seeds after they become well formed are consumed to only a very limited extent by stock, accounts in part for the unusual aggressiveness[1] of porcupine grass.

The palatability and forage value of the yellow brush dominant is comparatively low, so that where this species occurs in such abundance as appreciably to decrease the stand of other palatable plants the carrying capacity of the lands is considerably lower. While sheep and cattle browse the leafage and flower clusters to some extent, yellow brush can not be classed as a plant of sufficient forage value to be seriously considered in the management of the range with a view of increasing its abundance and luxuriance of growth.[2]

A large proportion of the secondary perennial species characteristic of the porcupine-grass-yellow-brush consociation, particularly the grasses, are probably first in importance among our valuable forage species. Practically all of the blue grasses, the fescues, the bromes, spiked trisetum, and mountain June grass, which occur in varying abundance throughout this consociation, are inferior to none as forage, cattle, sheep, and horses grazing them with relish at all times in the season. Likewise, some of the more conspicuous nongrasslike perennials, like yarrow, are good forage plants, though as a rule the nongrasslike species are grazed much more closely and with greater relish by sheep than by cattle and horses.[3] It is quite evident, therefore, that the porcupine-grass-yellow-brush lands generally are well suited to the common use of stock, that is, the joint grazing of cattle, horses, and sheep. In this respect, then, the porcupine-grass-yellow-brush consociation differs from that of the wheatgrass type, which in its highest development is best suited for the grazing of cattle and horses.

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[1] The seeds of porcupine grass are usually high in viability and reproduction is greatly fostered by the self-burial device of the seed, the alternate twisting and untwisting of the awn coupled with the sharp-pointed appendage at the base of the seed. For a discussion on this point see Journal Agri. Research, vol. 3, No. 2 : 118–119, 1913, and U. S. Department of Agriculture Bulletin No. 545 : 9–10, 1914.

[2] Sheep browse yellow brush with more relish than cattle. Because the foliage remains green late in the autumn after the herbage of most plants has dried up, sheep browse yellow brush more closely in the autumn than at any other time in the season. Even so, however, this plant furnishes only a small amount of rather inferior feed.

[3] Cattle and horses prefer grass to nongrasslike plants, such as weeds and browse. Sheep, on the other hand, prefer the weed and browse type, and consume a relatively small proportion of grass. Exception to this statement has been recorded when the grass is unusually palatable and the nongrasslike species are of an inferior kind. Therefore, where the vegetation consists of about the same amount of palatable weeds as of grass, the proportion of four sheep to one cow unit usually results in the most economic utilization of the forage crop. On a pure or practically pure grass range, on the other hand, cattle alone, or cattle and horses, usually afford the most economical utilization of the forage. On a strictly weed range the best utilization may be expected from the grazing of sheep only.

FORAGE PRODUCTION.

Calling forth, as it does, a conspicuous amount of blue grasses, some fescues, a scattered stand of wheat grasses, and other less important grasses, and at the same time permitting a number of the nongrasslike plants to persist, the porcupine-grass-yellow-brush consociation ranks high as forage. Expressed in terms of dry matter of palatable herbage per unit of surface, the porcupine-grass-yellow-brush consociation reaches its maximum production where the two dominant species are little more than holding their own in competition with the grasses higher in the scale of succession development; that is, where the highest possible development of the porcupine-grass-yellow-brush cover has been reached. Per unit of area, the uppermost development of this consociation, with its typically conspicuous admixture of highly palatable blue grasses, fescues, and other grasses, interspersed with numerous nongrasslike species, furnishes not only more feed but better herbage than any other forage combination that may occur in its lower developmental stages.

While the study has shown that a decrease in the stand of weedy species follows the progressive development of the consociation, it is seldom necessary to decrease the number of sheep that are grazed on the lands. Owing to the character of the feed, cattle rather than sheep should be increased in number to consume the additional grass forage, but the bulk of the nongrasslike herbage must be consumed by sheep. Except on a turfed grass range, a fair proportion of weeds, most of which are palatable to sheep but not to cattle and horses, is always present. Full utilization season after season of the grass herbage by cattle and horses tends to hold in check any striking increment in the grass cover, so that appreciable revegetation may be effected only where special methods of management are applied. Indeed, close utilization of the grass cover from season to season, as already indicated, has a tendency to decrease the grass stand and increase the stand of nongrasslike plants in much the same proportion, thus improving the conditions for the grazing of sheep.

SUMMARY OF THE PORCUPINE-GRASS-YELLOW-BRUSH CONSOCIATION.

The cover of small mountain porcupine grass and yellow brush, next to the wheat-grass consociation, constitutes the highest and most stable forage type. Accordingly where conditions become unfavorable to the maintenance of the wheat-grass cover, but not so adverse as drastically to change the fertility and available water content of the soil, porcupine grass and yellow brush soon gain dominion over the soil. Owing to the practical absence of turf-forming species within the porcupine-grass-yellow-brush consociation, precipitation penetrates deeply into the soil, hence both deep and shallow rooted

plants make up the ground cover in somewhat equal proportions. The highest development of the porcupine-grass-yellow-brush cover is indicated by a scattered stand of wheat grasses, a rather conspicuous presence of blue grasses (*Poa*), and a somewhat smaller amount of fescue grasses. The lower development of the type in question is characteristically indicated by the conspicuous presence of brome grass, and not uncommonly of fescue grasses, with the addition of several perennial nongrasslike plants, among which blue foxglove, sweet sage, and yarrow are the most common.

So long as porcupine grass and yellow brush, including the typical associated species, hold their place in competition with plants of lower successional stages, or yield to the invasion of plants higher in the cycle of succession, like the wheat grasses, it is perfectly clear that the range is not being misused. If, on the other hand, the porcupine-grass-yellow-brush consociation is being replaced by brome grasses, fescues, and more especially by blue foxglove, sweet sage, yarrow, and other plants of the second weed stage, there is indisputable evidence of the deterioration of the range.

In view of the large variety of palatable plants associated with the porcupine-grass-yellow-brush cover, the highest possible development of this type is probably the most desirable of any for the grazing of all classes of stock. Since the forage crop is composed both of weeds and grasses, with the latter distinctly predominating on the better developed types, the highest grazing efficiency is obtained through "common use," that is, through the combined grazing of cattle, horses, and sheep.

THE FOXGLOVE-SWEET-SAGE-YARROW CONSOCIATION.

Detailed quadrat data and extensive observations have shown that when conditions unfavorable to growth are sufficiently prolonged gradually to destroy the porcupine-grass-yellow-brush cover, but not such as seriously to change the condition of the soil, shallow-rooted perennial weeds of the second weed stage, notably blue foxglove (*Pentstemon procerus*), sweet sage (*Artemisia discolor*), and yarrow (*Achillea lanulosa*) are the natural successors. On the other hand, where the porcupine-grass-yellow-brush cover is suddenly destroyed and considerable portions of the upper soil layer carried away, as often takes place where live stock are injudiciously handled, the immediate successional cover consists chiefly of annual plants characteristic of the first or early weed stage, with or without an admixture of perennial species.

In the gradual elimination of the porcupine-grass-yellow-brush cover perennial weed species usually gain a foothold shortly after the ground is exposed or when the roots of the grass and brush cover

no longer bind the soil firmly. The usual increase in the available soil water resulting from the lowered absorption and transpiration power of the former cover greatly favors the germination, growth, and reproduction of the perennial weeds. Generally, however, where the cover has been below normal in density for a number of years, the humus content, and, indeed, the water-holding power of the soil is lower than on the more densely covered lands, so that germination and invasion of the species which immediately precede the porcupine-grass-yellow-brush consociation is less vigorous than where the grass-brush stand has just been destroyed.

In the degree of invasional aggressiveness, little difference has been observed among the three dominants; all have fairly strong seed habits. Once the plants are well established, however, yarrow easily leads in the rate of spread, the blue foxglove being the least aggressive, and the sweet sage rather intermediate between the two. This behavior is significant in view of the fact that the rootstocks of the species concerned are practically equal in length.

As to the longevity of the dominant species few data are available. Owing to the relatively high palatability of the yarrow, however, this species is usually the first to give way under excessive grazing.

Because of the slight difference in moisture requirements, the three species are often closely associated, but they seldom occur in equal density. When fully developed the plants form a matlike growth more or less pure in stand. The most luxuriant and permanent stand of blue foxglove is found on protected, moderately moist habitats, while yarrow and sweet sage occur in rather close association in somewhat drier situations.

Regardless of the density of the cover of the foxglove-sweet-sage-yarrow consociation, a scattered stand representing a large number of secondary species occurs in association with the dominants. Among the grasses occasional specimens of large mountain brome grass (*Bromus marginatus*), nodding brome grass (*B. porteri*), Scribner's wheat grass (*Agropyron scribneri*), onion grass (*Melica bulbosa*), and showy onion grass (*M. spectabilis*) are characteristic. Of the more conspicuous nongrasslike plants, the most typical are aster (*Aster frondeus*), horsemint or giant hyssop (*Agastache urticifolia*), mountain dandelion (*Crepis acuminata*), geranium (*Geranium viscosissimum*), sneezeweed (*Helenium hoopesii*), rubberweed (*Hymenoxys floribunda*), Sampson's mertensia (*Mertensia sampsonii*), cinquefoil (*Potentilla filipes*), false cymopterus (*Pseudocymopterus tidestromii*), and butterweed (*Senecio columbiana*).[1]

The root systems of blue foxglove, sweet sage, and yarrow are largely superficial in character, so that the water supply is derived

[1] Congeneric species of the plants here named occur in varying abundance.

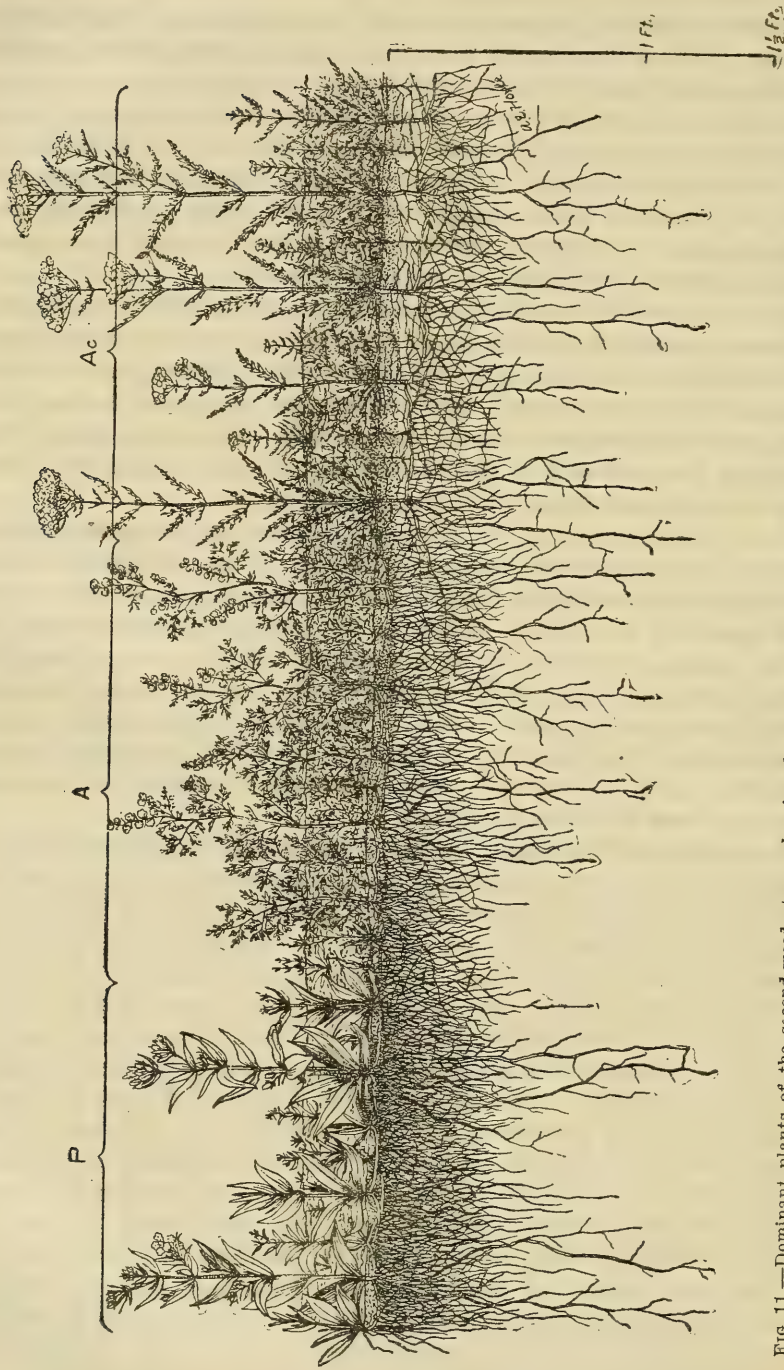


FIG. 11.—Dominant plants of the second-weed stage, showing habits of growth. *P*, Blue foxglove (*Pentstemon procerus*); *A*, sweet sage (*Artemisia discolor*); *Ac*, yarrow (*Achillea lanulosa*).

chiefly from the first foot of soil (fig. 11). The surface soil is somewhat matted but seldom bound so firmly as entirely to prevent the presence of other species. Where the second-weed stage is well established little serious erosion takes place.

CONDITIONS OF GROWTH AND PRODUCTION.

The foxglove-sweet-sage-yarrow consociation thrives wherever conditions are favorable to the growth of porcupine grass and yellow brush, and even where the soil is not so good. As in the porcupine-grass-yellow-brush consociation, however, the best development of the dominant species of the second-weed stage is found where the soil is fairly well decomposed, mellow, and reasonably moist. In general, the waterholding power of the soil is lower where the perennial weed species predominate than where plant types higher in the succession prevail. This difference in the water-holding capacity of the soil is also associated with differences in soil fertility, and to some extent at least with its physical texture, as Table 2, showing the relative chemical properties of typical soil samples, would imply. The soil representing the porcupine-grass-yellow-brush cover is richer than the soil characteristic of the second-weed stage in all chemical constituents here considered, and the difference in the total organic matter of 81 per cent in favor of the porcupine-grass-yellow-brush soil is particularly significant. Aside from the fact that this high percentage of organic matter implies the presence of correspondingly large amounts of available nitrates and other plant foods, it has a direct bearing upon the water-holding capacity and the power of water retention of the soil. The average difference in the available water content of the soil samples was 4.6 per cent in favor of the porcupine-grass-yellow-brush area. Obviously, blue foxglove, sweet sage, yarrow, and the associated species will thrive on the moister and richer soils; but owing to more highly developed root systems, greater longevity, and other life-history characteristics of the plants of the higher developmental stages, the second-weed-stage species are sooner or later forced to yield their places to the more permanent species. However, plants of the foxglove-sweet-sage-yarrow consociation, particularly the dominant species, are comparatively resistant to drought, and maintain themselves well under adverse climatic conditions.

TABLE 2.—*Average chemical properties of typical soil samples taken from the surface to a depth of 6 inches of an area supporting a cover of foxglove, sweet sage, and yarrow, and of similar samples representing soil supporting a cover of porcupine grass and yellow brush.*

Samples.	Total lime (CaO).	Carbon dioxide (CO_2).	Calcium carbonates ($CaCO_3$).	Organic carbon.	Total nitrogen.	Nitrates (parts per million of dry soil).	Total organic matter.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*		*Per cent.*
Foxglove, sweet-sage, and yarrow cover	1.03	0.08	0.18	1.52	0.17	11	3.03
Porcupine-grass and yellow-brush cover	1.13	0.10	0.38	3.20	0.35	17	5.60

The blue foxglove, sweet sage, and yarrow reproduce mainly by means of rhizomes or rootstocks; and like most high mountain plants which give rise to new individuals by vegetative means, their seed habits are only moderately strong. Germination tests conducted from 1914 to 1916, inclusive, gave the following average percentages:

Blue foxglove	11.8
Sweet sage	14.2
Yarrow	9.3

In addition to the low viability of the well-filled seeds, a rather small seed crop is produced, a large proportion of the flowers either not being fertilized or failing to develop after fertilization. However, where the soil is exposed and conditions favor germination and growth, seedlings of varying density and vigor are in evidence. Three years are required for the developmental cycle of most species—that is, from the time of germination of the seed until the resulting plant produces viable seed and gives rise to new individuals. Some species send up one or more flower stalks late in the second year following germination, but, as a rule, no fertile seeds are produced until in the third year of growth. By the end of the third season, the rootstocks are well formed, so that reproduction both by vegetative means and by seed usually takes place more or less simultaneously.

THE EFFECT OF DISTURBING FACTORS.

Like the vegetation composing the types already discussed, the foxglove-sweet-sage-yarrow cover readily replaces itself where the edaphic conditions are not appreciably changed as a result of the cover being eliminated or thinned out. Where the physical or chemical conditions of the soil are rendered less favorable to growth than formerly, however, several species lower in the succession promptly gain dominion over the soil. Among the first and most reliable

species to announce the waning or retrogression of the foxglove-sweet-sage-yarrow cover are certain inconspicuous, rather short-lived perennials which usually occur very sparsely in association with the dominants of the second-weed stage. By far the most aggressive and reliable indicators of degeneration are low pea vine (*Lathyrus leucanthus*), evening primrose (*Lavauxia flava*), false cymopterus (*Pseudocymopterus tidestromii*), Mexican dock (*Rumex mexicanus*), false Solomon's seal (*Vagnera stellata*), and tongue-leaved violet (*Viola linguæfolia*). These rather temporary second-weed-stage species obtain the greater part of their moisture supply below the first foot of soil (figs. 12, 13, and 14.) Except in the case of low pea vine and false Solomon's seal, their root systems are on the taproot order, most of the species having well-developed laterals, many being several inches long. With the exception of low pea vine and false Solomon's seal, which reproduce profusely by rhizomes, new individuals arise only from seed. Considering the elevation and the conditions of growth, the four species whose regeneration depends entirely upon seed have strong seed habits. Low pea vine and false Solomon's seal, on the other hand, produce only a small amount of seed per plant, but the viability of the seed is nevertheless relatively high, as Table 3 shows.

TABLE 3.—*Viability of seed crop of short-lived perennial weeds produced in 1914–1916, inclusive.*[1]

Plant.	Viability of seed.		
	Average.	Maximum.	Minimum.
	Per cent.	*Per cent.*	*Per cent.*
Tongue-leaved violet	52.7	78.4	20.5
Evening primrose	33.1	35.4	26.4
Low pea vine	29.4	36.8	17.3
False cymopterus	19.9	28.7	11.2
Mexican dock	16.3	28.1	6.3

[1] Seed was collected from a number of specimens of each species grown in different soils and in different exposures so that, presumably, the figures given are representative for the seasons in question.

In view of the fact that tongue-leaved violet is the most aggressive invader immediately subsequent to the destruction of the foxglove-sweet-sage-yarrow cover, it is interesting to note that the viability of the seed of this species is superior to that of its associates. While it may be true that enough more viable seeds are produced by the competing plants to equal, or indeed exceed, the total number of viable seeds of tongue-leaved violet, it is not improbable that under field conditions, the seeds of the violet, with their higher germination strength, may outnumber those of high germination power in the species having an appreciably lower percentage of viability.

Next to tongue-leaved violet, evening primrose is the most aggressive and abundant. This species is followed in aggressiveness by

FIG. 12.—Plants characteristic of the early second-weed stage.

Mexican dock, the increase in which is held in check to an appreciable extent, however, by the fact that it is relished more by stock

than the associated species. Low pea vine, because of its profusion of long rootstocks (fig. 12), and the rapid rate at which new shoots arise vegetatively, forms the densest cover of any of these rather temporary species.

The further exposure and depletion of the soil usually brings forth a conspicuous admixture of a number of other short-lived perennial species, some of which may predominate for a time. The most characteristic of these are mountain rock cress (*Arabis drummondii*),

FIG. 13.—Plants characteristic of the early second-weed stage.

low larkspur (*Delphinium menziesii*), scarlet gilia, (*Gilia pulchella*), peppergrass (*Lepidium ramosissimum*), bladder pod (*Lesquerella utahensis*), plantain (*Plantago tweedyi*), and butterweed (*Senecio columbianus* and *S. crassulus*). Very few grasses are associated with this cover. Like their immediately superior associates successionally considered, the roots of most of these species are specialized, or of the tap order, with more or less conspicuous lateral feeders. Generally the roots are rather shallow, the moisture supply being procured chiefly from the upper foot of soil (figs. 15 and 16).

No systematic attempt has been made to determine the viability of the seed crop of these secondary weed species, but various laboratory tests and field observations indicate that the germination strength of the seed is high. This lower successional stage of vegetation, like the second-weed consociation generally, is early maturing, earlier, in fact, by 10 days or so than the wheat-grass cover, so that as a rule plants mature their seeds and the herbage dries up well in advance of the occurence of killing frosts. The herbage of most of the species, however, cures poorly. On some lands these species are so closely associated with low pea vine, evening primrose, false cymop-

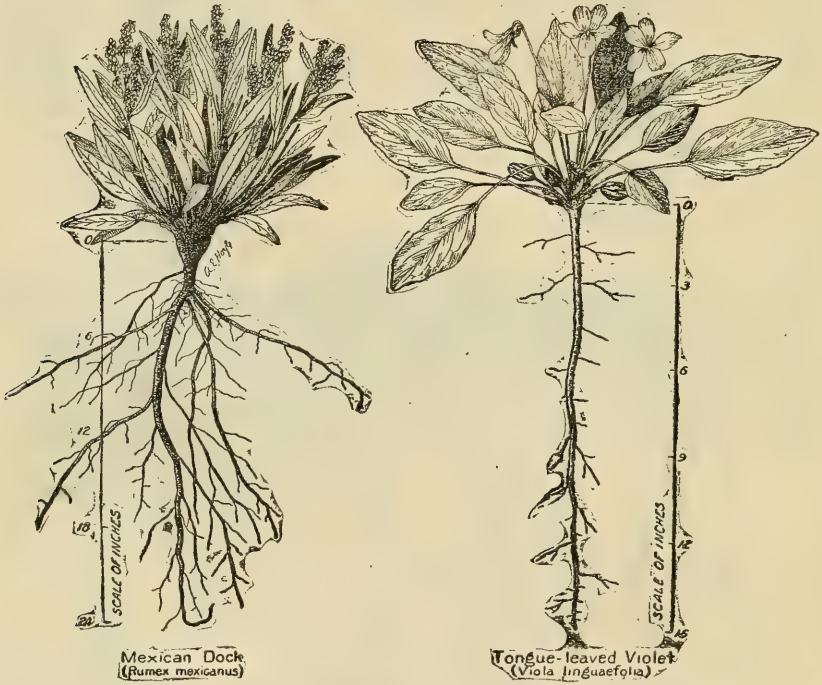


FIG. 14.—Plants characteristic of the early second-weed stage.

terus, Mexican dock, and tongue-leaved violet that it is difficult to recognize where one set supersedes the other. Generally, however, the line of demarcation is fairly distinct. As a rule the latter group is associated with a larger percentage of annual plants than the former, though this varies somewhat with the density of the cover of perennial plants, moisture conditions, and numerous other factors. In the absence of a nurse cover, such as shrubby plants or other robust and conspicuously branched perennials, it is evident that a site supporting the lower successional cover of the second-weed stage is at best severe and less favorable to germination and establishment than are sites supporting a higher type of vegetation.

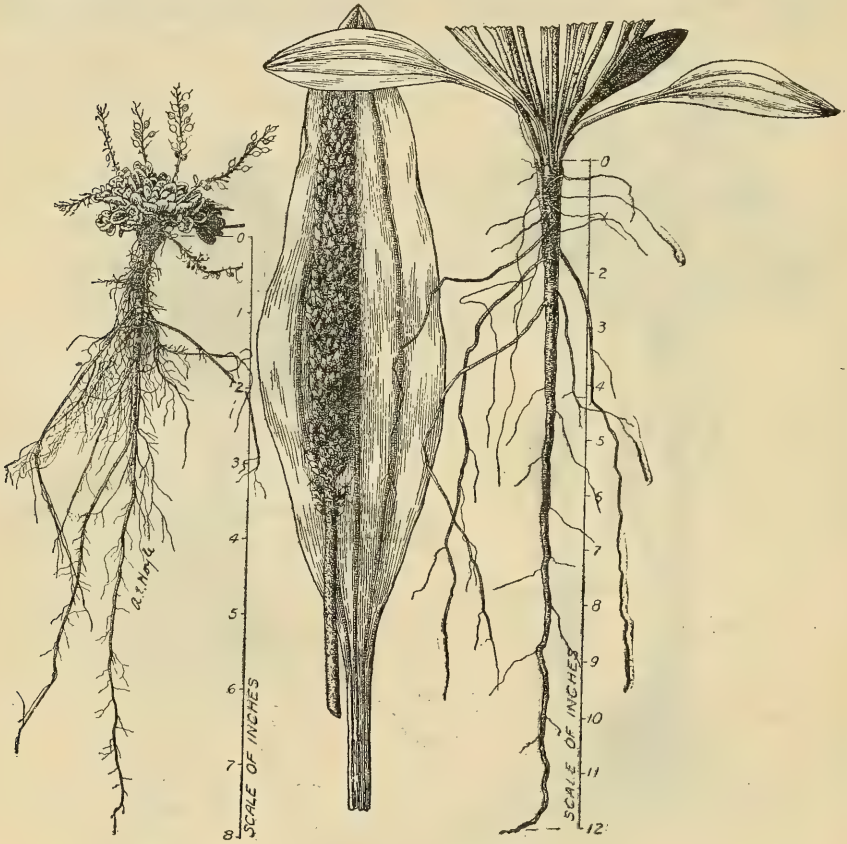
PALATABILITY.

The profusion of weedy or nongrasslike plants and the scattered occurrence of grasses make the foxglove-sweet-sage-yarrow consociation best suited for the grazing of sheep. In general, only the grasses and a very few of the nongrasslike species of the vegetation characteristic of the second stage are eagerly grazed by cattle and horses. These constitute only a very small proportion of the plant

FIG. 15.—Plants characteristic of the early second-weed stage.

cover. While, as already stated, sheep crop a grass range less closely than cattle and horses, sheep nevertheless eat the herbage of grasses where such feed constitutes only a relatively small part of the total forage crop. Most of the nongrasslike plants are grazed more or less closely by sheep. Therefore, the highest possible utilization of the second-weed-stage type is obtained by the grazing of sheep, provided, of course, the animals are properly handled.

The relative palatability and forage value of the different species making up the second-weed-stage consociation are summarized in Table 4. Palatability is here classed as high, medium, low, negative, and objectionable; abundance as dense, moderately dense, scattered, and very scattered. Of the 27 species listed, 17, or 63 per cent, are either highly or moderately palatable to sheep; while only 9, or 33



Bladder pod (*Lesquerella utahensis*). Plantain (*Plantago tweedyi*).

FIG. 16.—Plants characteristic ofthe early second-weed stage.

per cent, and 5, or 18 per cent, are either highly or moderately palatable to cattle and horses, respectively. Those of low forage value number 8, or 30 per cent, in the case of sheep, none being listed as negative in forage value; in the case of cattle 16, or 59 per cent, are low or negative in palatability; and in the case of horses 20, or 74 per cent, are listed in the same category. The species of greatest abundance are much more palatable to sheep than to cattle and horses. Accordingly, it is evident that, so far as the forage is con-

cerned, much higher utilization will be obtained by cropping the second-weed-stage cover by sheep than by cattle and horses.

TABLE 4.—*Comparative palatability and forage value of the plants characteristic of the second weed stage.*

Plant.	Palatability.			Abundance.[1]
	Sheep.	Cattle.	Horses.	
Aster	Medium	Low	Negative	Moderately dense.
Bladder pod	Low	Negative	do	Scattered.
Blue foxglove	Medium	Low	do	Dense.
Butterweed	High	Medium	Low	Scattered.
Cinquefoil	Medium	Low	Negative	Do.
Evening primrose	do	do	do	Do.
False cymopterus	Low	Negative	do	Do.
Geranium	Medium	Low	Low	Moderately dense.
Horsemint	Low	do	Negative	Scattered.
Large mountain brome grass	High	High	High	Moderately dense.
Low pea vine	Medium	Low	Low	Do.
Mexican dock	do	do	Negative	Very scattered.
Mountain dandelion	High	Medium	Low	Scattered.
Mountain rock cress	Low	Negative	Negative	Very scattered.
Nodding brome grass	High	High	High	Scattered.
Onion grass	Low	Medium	Medium	Do.
Peppergrass	do	Negative	Negative	Very scattered.
Plantain	Medium	Low	do	Do.
Rubberweed	Objectionable	Objectionable	Objectionable	Scattered.
Sampson's mertensia	High	High	Low	Do.
Scarlet gilia	Medium	Low	Negative	Do.
Scribner's wheat grass	Low	Medium	Medium	Do.
Showy onion grass	do	do	do	Do.
Sneezeweed	Objectionable	Objectionable	Objectionable	Do.
Sweet sage	Medium	Low	Negative	Dense.
Tongue-leaved violet	do	do	do	Scattered.
Yarrow	High	Medium	Low	Dense.

[1] Abundance as here used takes into account the size of the plant and its herbage production as well as the density in which it occurs.

FORAGE PRODUCTION.

As compared with the porcupine-grass-yellow-brush consociation, the carrying capacity, acre for acre, is notably less on the foxglove-sweet-sage-yarrow type, regardless of the class of stock grazed. Even if used by sheep, the more superior second-weed-stage type will probably support only 50 per cent as many year after year without injury to the range, as will an equally desirable cover of the porcupine grass and yellow brush. In the absence of a sufficient stand of grasses and other desirable late-maturing plants the herbage of the second-weed stage is highly succulent; and while palatable and conducive to the production of large gains in the case of sheep it does not produce fat which is as solid or as permanent as that which characterizes the condition of the animal when it eats a fair balance of grasses and of other late-maturing plants. Cattle and horses little more than maintain their weight on a range distinctly in the second-weed stage. The acreage required per cow is proportionately much greater on a range in the second-weed stage than on a porcupine-grass-yellow-brush cover or on a wheat-grass area. Relatively little of the palatable feed is grazed either by sheep or cattle after the plants reach maturity or after killing frosts have occurred.

SUMMARY OF THE FOXGLOVE-SWEET-SAGE-YARROW CONSOCIATION.

The foxglove-sweet-sage-yarrow cover, less specifically known as the second or late weed stage, is the initial type in the retrogressive succession of the porcupine-grass-yellow-brush consociation. The more characteristic plants of this weed stage generally are comparatively aggressive where the conditions of growth are reasonably favorable. A rather large number of species are associated with the foxglove-sweet-sage-yarrow type species, though they seldom occur as dominants. By far the greater number of the secondary plants are nongrasslike. A few grasses are present, however, among which large mountain brome grass is by far the most important.

The type species and several of the secondary plants reproduce both vegetatively and by seed. In several species vegetative reproduction is so active as to produce a loose matlike ground surface. Most of the plants are shallow-rooted. When the soil conditions become unfavorable for the maintenance of the foxglove-sweet-sage-yarrow cover an aggressive succession of shallow-rooted, relatively short-lived perennial plants in association with a number of annual species usually takes place. In instances of severe soil depletion annual species invariably predominate.

Low pea vine, evening primrose, false cymopterus, Mexican dock, and tongue-leaved violet are the most reliable and characteristic initial indicators of the destruction of the more stable second-weed-stage cover. If the disturbing factor continues to operate, these rather short-lived perennials are sooner or later superseded by annual plants.

Much less dry matter and notably less palatable feed are produced on the late-weed-stage type than on the wheat-grass or on the porcupine-grass-yellow-brush consociations. The profusion of weed or nongrasslike plants and the small amount of grass forage produced makes the second-weed-stage cover better suited for the grazing of sheep than for cattle and horses. Owing to the fact that sheep graze nongrasslike plants with considerably greater avidity than cattle and horses, the foxglove-sweet-sage-yarrow consociation can be fully utilized by the grazing of sheep alone. Sheep, however, will not show as much progress on the second-weed-stage consociation as on the porcupine-grass-yellow-brush consociation. The gains may be fairly large but the fat is not of a solid character. Cattle and horses do poorly on the late weed type. As a rule, they little more than maintain their weight.

THE RUDERAL-EARLY-WEED CONSOCIATION.

Soils which were formerly rich but which have been so seriously impaired that their fertility is similar to that of relatively new soils recently invaded by herbaceous plants, support virtually the same

type of vegetation as do the new soils.[1] The cover consists essentially of ruderal or annual plants, mostly weeds. This colonization of the early-weed stage continues until enough organic matter has accumulated in the soil to favor the invasion and establishment of the second or late weed stage.

The density of the cover varies greatly according to the character of the soil, the seed crop available for germination, and the growth condition of the current season; the cover may be quite dense one year and relatively sparse the next. When one good growing season follows another the cover is particularly dense and the individual plants are large; also the pioneer species of the second or late weed stage usually begin to appear. A succession of dry years, on the other hand, brings forth a sparse stand of the first, or early weed stage, the plants of which are small; also the pioneer species of the second weed stage are usually absent.

The most typical and abundant species of the first-weed stage are goosefoot or lamb's-quarters (*Chenopodium album*), slender-leaved collomia (*Collomia linearis*), tarweed (*Madia glomerata*), Tolmie's orthocarpus (*Orthocarpus tolmiei*), Douglas knotweed (*Polygonum douglasii*), and tansy mustard (*Sophia incisa*) (figs. 17 and 18). Less abundant, but usually associated with the above species are androsace (*Androsace diffusa*), gilia (*Gilia micrantha*), peppergrass (*Lepidium ramosissimum*), monolepis (*Monolepis nuttalliana*), and knotweed (*Polygonum aviculare*).

In general the first-weed-stage cover reaches maturity earlier than any other. Because of the shallow roots and the lack of conspicuous laterals, this cover is of little value in checking erosion or otherwise preserving the watershed. The root systems are essentially of the specialized or tap character, and are confined almost entirely to the upper foot of soil—indeed the roots of the majority of the species do not penetrate deeper than about 8 inches. Therefore, where the topography, soil, climatic conditions, and other factors favor torrential runoff, the ruderal-weed stage is of the least value of any in protecting the watershed from erosion.

CONDITIONS OF GROWTH AND REPRODUCTION.

No group of perennial plants has as strong seed habits and is subject to as few failures in seed production as the first-weed-stage species. While no systematic study has been made to ascertain the size and viability of the seed crop, observations and repeated germination tests indicate that the normal seed crop is unusually large and fertile. Germination tests of well-developed seed of Douglas knotweed and

[1] Soils heavily packed, which often takes place when stock (especially sheep) trample denuded or sparsely vegetated areas excessively, also commonly support only ruderal or annual plants.

tansy mustard, for example, have averaged more than 70 per cent, considerably exceeding the highest average seed-test records of perennial species. Generally, the seed of the more aggressive annuals are plump and well filled with reserve food. Another distinct advantage observed in the case of the seed of the ruderal weed species

Goosefoot or lamb's-quarters (*Chenopodium album*).

Slender-leaved collomia (*Collomia linearis*).

FIG. 17.—Plants characteristic of the first or early weed stage.

is their ability to germinate under conditions of temperature adverse to most plants. Seed of Douglas knotweed, tansy mustard, and tarweed, for instance, have been observed to sprout when the maximum diurnal temperature has not exceeded 50° Fahrenheit, the

mean temperature being 42°, and when the nocturnal temperature has dropped from 2° to 4° below freezing. Few perennial plants, even though restricted in their distribution to the subalpine zone, are capable of germination at such low temperatures. Being entirely dependent upon seed for their perpetuation, obviously only those annuals persist or are conspicuous which are capable of germinating and becoming established at the earliest advent of spring.

Tolmie's orthocarpus (*Orthocarpus tolmiei*). Douglas knotweed (*Polygonum douglasii*). Tansy mustard (*Sophia incisa*).

FIG. 18.—Plants characteristic of the first or early weed stage.

Since the ruderal-early-weed stage represents the lowest or most primitive herbaceous cover possible, it will be instructive to compare briefly the conditions of growth of this type with those of the highest herbaceous successional cover, the wheat-grass consociation. For the purpose of ready comparison the average, maximum, minimum, and optimum depths of the roots of the most characteristic ruderal-weed species and of the chief wheat grasses are tabulated in Table 5. While the depth of penetration of the roots of wheat grasses as a whole is appreciably greater than in the ruderal weed species, small wheat grass obtains its water supply from much the same soil stratum

as the ruderal-weed species. Blue bunch wheat grass and slender wheat grass, on the other hand, absorb nearly all of the water they need from soil far below the deepest penetration of roots of the annual plants.

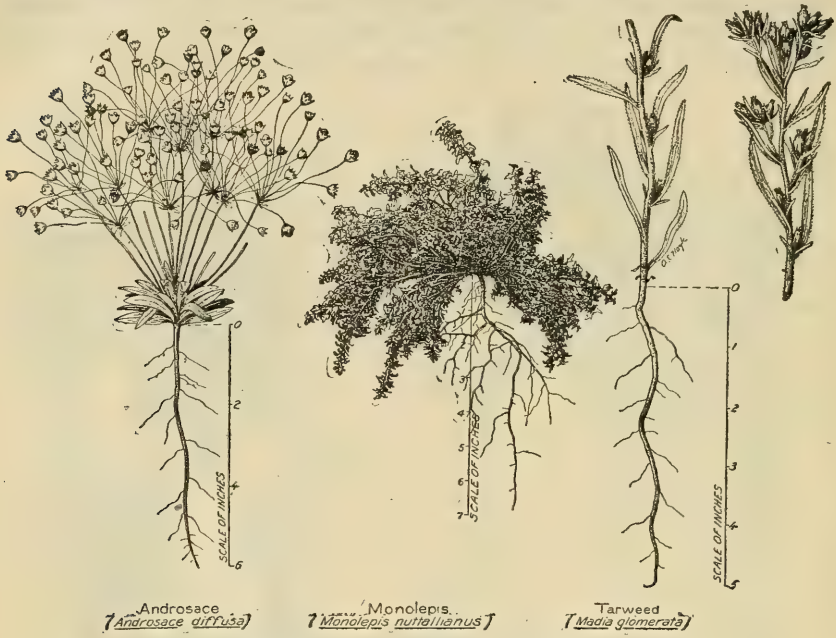


FIG. 19.—Plants characteristic of the first-weed stage.

TABLE 5.—*Comparative depth of roots of typical ruderal-weed species and of the chief wheatgrasses.*

Plant.	Depth of roots in inches.		
	Maximum.	Minimum.	Optimum.
Ruderal-weed species:			
Goosefoot	7	3	5.5
Slender-leaved collomia	9	3.5	6
Tarweed	10	4	7
Tolmie's orthocarpus	8	3	5
Knotweed	11	4	7
Douglas knotweed	10	4	7
Tansy mustard	9	3	6
Average	9.1	3.5	6.2
Wheat grasses:			
Small wheat grass	15	6	8
Blue bunch wheat grass	40	26	32
Slender wheat grass	40	26	32
Average	31.7	19.3	24

The rate of percolation of water is much greater on the ruderal-weed lands than on the small wheat-grass areas. This is due not only to the dense matlike growth of the roots characteristic of the

small wheat-grass cover, but also to the comparatively high proportion of humus, and hence water-holding power, of the wheat-grass soil.

Data showing the more important chemical constituents and humus content of representative soils supporting short wheat grass and of soil supporting ruderal weeds are given in Table 6. Except in the amount of potash, the percentage of the chemical constituents important as plant food is higher in the soils representing the small wheat-grass lands than in the soils characteristic of the ruderal-weed cover. The most striking difference is found in the total nitrogen

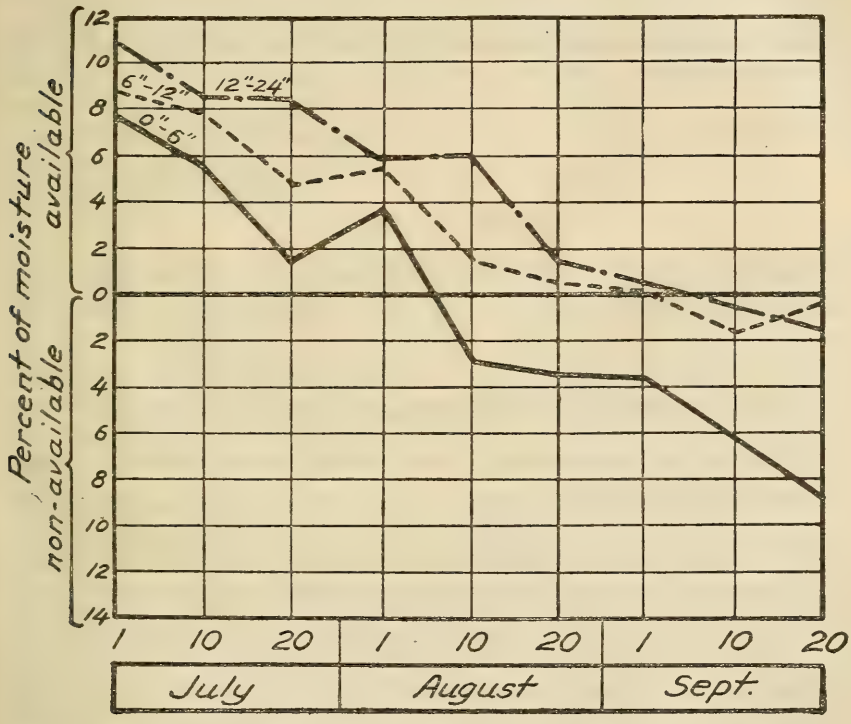


FIG. 20.—Available and nonavailable soil moisture on an overgrazed area supporting a sparse stand of ruderal vegetation, 1915.

content. Also there is a wide difference in the humus content as determined by incineration.

TABLE 6.—*Chemical properties of soil supporting small wheat grass and soil supporting the ruderal-weed consociation.*

Soil.	Lime (CaO).	Potash (K_2O).	Phosphoric acid (P_2O_5).	Total nitrogen.	Loss by ignition (humus).
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Small wheat grass	1.49	1.30	0.38	0.488	14.65
Ruderal weed	1.26	1.53	.22	.158	6.64

The wide difference in the humus content accounts chiefly for the higher water-holding power and available plant water in the wheat-grass soil, which, when it was saturated, were greater by 10.4 per cent than in the soil which supported the ruderal-weed vegetation. In order to determine what effect this difference in fertility and available water might have on the growth and water requirements of vegetation, experiments were made on three batteries each of the selected soils.[1] The vegetative development and the total water requirements of the plants grown in the wheat-grass soil and in the ruderal-weed soil are shown in Table 7.

TABLE 7.—*Summary of vegetative growth and water requirements of peas and wheat developed in soils characteristic of the wheat-grass type and of the ruderal-weed cover.*

Plant.	Peas.		Wheat.	
	Ruderal-weed soil.	Wheat-grass soil.	Ruderal-weed soil.	Wheat-grass soil.
Number of leaves	42	112	22	47
Leaf length ... mm	791	2,634	4,474	10,080
Dry weight ... grams	0.79	6.55	5.52	12.09
Water used per plant ... do	667	3,051	2,516	3,820
Water requirement per unit dry matter ... do	841	467	472	343

Both wheat and peas show a striking contrast in the vegetative growth and in the water requirements in the two soil types. The

[1] The batteries were so arranged that no water escaped from the soil except by transpiration from the plants grown.

After being carefully sifted, the soils were moistened so as to contain approximately 30 per cent of water. The soil was thoroughly mixed, so that the moisture content was uniform throughout, and was firmly packed in heavy galvanized-iron potometers, 17 inches high and 14 inches in diameter. Potometers of this size, having as they do a capacity of about 90 pounds of air-dry soil, provided a soil mass of ample space for development and spread of the roots of the plants selected to be grown in the potometers. The potometers were fitted with lids of the same material as the cans, and five equally spaced holes three-fourths inch in diameter were punched in each for the plants. In the center of the cover a hole 1½ inches in diameter was provided, which was used in watering and which was fitted with a cork stopper and capillary tube for the circulation of air. Before the lid was put on sufficient soil was removed from the surface center of the can for the placing of a granite receptacle 4 inches in height and 5 inches in diameter, perforated centrally in the bottom and underlaid with 1½ inches of gravel. This greatly facilitated the addition of water. After the lids were placed the space between the rim and can was closed by securely sealing with strips of surgeon's adhesive tape, which, when dry was coated with shellac. In order to have as little variation as possible in the individual plants, pedigreed strains of Canadian field peas (*Pisum arvense*) and cultivated wheat (*Triticum durum*), known as Kubanka 1440, were used. In order further to insure uniformity in the plants the seeds were sprouted between moist blotters and the most vigorous sprouts transferred to water cultures from which uniformly sized plants were subsequently selected for planting. In planting, a small amount of soil was removed through the perforations made in the lid, the roots of the sprouts were inserted, and the soil was firmly pressed about the roots. A combination of melted beeswax and tallow was used to seal over the soil exposed by the perforations made in the lid of the potometer through which the plants were inserted. The methods used in sealing and in watering were essentially the same as those devised by Briggs, L. J., and Shantz, H. L., "Water Requirements of Plants," U. S. Department of Agriculture, Bureau of Plant Industry Bulletin 284: 8–14. 1913.

vegetative development was appreciably greater in the wheat-grass soil both in the number of leaves produced and in the total leaf length. The difference in the development of the plant as a whole is best expressed by the dry weight produced. In peas the proportion of dry weight was as 1 to 8.2 in favor of the wheat-grass soil; in wheat the proportion was as 1 to 2.2 in favor of the same soil type. The water requirement for the production of a given unit of dry weight, on the other hand, was much greater in the ruderal-weed soil than in the wheat-grass soil, the proportion being approximately 2 to 1 in peas and 2 to 1.4 in wheat.

The higher water requirement of plants grown in the less fertile soil is particularly significant in view of the fact that impoverished soils absorb and retain very much less water than do the more fertile soils. This fact, coupled with the low fertility of the soil, chiefly accounts for the presence of the temporary weed cover on badly-impoverished, as well as newly-formed soils.

SOIL WATER CONTENT.

The soil moisture conditions on a first-weed-stage area during the season of 1915 are summarized in figure 20. Considering the general trend of the curves representing the available water content from 0 to 6 inches, 6 to 12 inches, and 12 to 24 inches in depth by 10-day periods throughout the growing season, it will be observed that there is a rather sharp decline in the water content of the soil from July 1 to September 20. Except in the last period (September 10 to 20) the highest amount of available plant water was found in the 12 to 24 inch layer. The 0 to 6 inch soil layer, on the other hand, contained the lowest water content throughout the entire period. When saturated the upper 6 inches of soil, except where severe washing has occurred, usually contains several per cent more moisture than the soils of greater depth. The reduction in the water content of the upper soil layer is, of course, chiefly attributable to transpiration[1] and to a slight extent to direct evaporation from the soil.[2]

The most important physiological fact brought out in the graph is the period at which the soil water content becomes unavailable to the vegetation. In the case of the all-important upper 6 inches of soil, from which the first-weed-stage plants procure by far the greater part of their moisture supply, the water becomes unavailable to the vegetation between August 1 and August 10. In the 6 to 12

[1] Germination and growth in the case of this cover in 1915 began on June 23.

[2] Loss of water by direct evaporation from the soil is slight as compared with that lost by transpiration from the vegetation. For a discussion on this subject see Burr, W. W., "Storage and Use of Soil Moisture." Research Bulletin, No. 5, Agricultural Experiment Station of Nebraska: 61: 1914. Also Romistrov, V. G., "The Nature of Drought According to the Evidence of the Odessa Experimental Field." M. L. and A. Department of Agriculture, Odessa: 17: 1913.

inch and the 12 to 24 inch soil layers there was available water until about September 10. Because of the desiccation of the upper soil layer during the first few days in August at least 90 per cent of the vegetation ceased to function. While the rate of growth and the period of maturity vary according to the character of the season, the ruderal-weed cover generally requires only about six weeks in which to complete growth and mature its seed crop.

THE EFFECT OF DISTURBING FACTORS.

The edaphic conditions of few of the deeper and older mountain soils are so adverse as entirely to exclude the first-weed-stage plants. But the density of the cover of the type in question is controlled largely by the proportion of available moisture contained in the soil during the germination period. Likewise the luxuriance of the stand is determined chiefly by the available moisture content during the growing season.

Thorough colonization of the ruderal-weed species for three or more years, in the absence of the play of factors adverse to the unhampered development of the vegetation, generally calls into evidence an admixture of the more aggressive, short-lived species of the second-weed stage, hence marks the initial passing of the ruderal-weed cover. On the other hand, the removal of a large proportion of the soluble plant foods, and indeed of portions of the soil itself, is followed by a distinct retrogression of the first-weed-stage vegetation. Where the destruction of the soil is continued to the extent that the "holdfast" of the ruderal-weed type is destroyed, the pioneer stage of plant life—the algæ and lichens—again appears over the exposed rocks.

PALATABILITY.

With the exception of a very few plants, the ruderal-weed consociation affords little feed for stock. A large number of the plants are cropped by sheep at least to a limited extent, but they afford only a small amount of forage. Cattle graze only a few species, and horses consume practically none. The most palatable plant to sheep and cattle is tansy mustard, the flowers, leafage, and the more tender parts of the stem being devoured with unusual relish until the plant reaches maturity; after that, like nearly all of the first-weed-stage species, it is not grazed noticeably at all. Tansy mustard, however, occurs so scatteringly over the type as a whole that it is of little value as a forage plant. Douglas knotweed, the most abundant of the ruderal-weed species, is grazed to a considerable extent by sheep before the seed is disseminated, apparently with good results to the animals. It probably furnishes more feed than all the rest of the annual species combined. Cattle also graze Douglas knotweed,

though with less relish than sheep. Several of the more conspicuous plants, like tarweed, gilia, etc., are practically disregarded by stock.

FORAGE PRODUCTION.

The amount of forage produced on lands in the first or early weed stage is far less than that on lands supporting any of the higher stages of plant growth. Like the second or late weed cover, the ruderal-weed cover is best suited for the grazing of sheep, but the carrying capacity is exceedingly low and the forage distinctly inferior. Aside from the fact that little of the herbage produced is grazed after about the first week in August, anything approaching complete utilization of the forage crop is apt to stimulate erosion of a most destructive character. Hence range lands in the ruderal-weed stage must be managed in the most expert way; anything approaching maximum utilization is hardly to be considered if the more permanent and desirable cover is ultimately to gain dominion over the soil.

SUMMARY OF THE RUDERAL-EARLY-WEED CONSOCIATION.

On lands where the soil has been so seriously impaired as no longer to afford a congenial habitat for the growth of perennial species, the cover consists essentially of annual plants. This first or early weed stage of which goosefoot or lamb's-quarters, slender-leaved collomia tarweed, Tolmie's orthocarpus, Douglas knotweed, and tansy mustard are typical examples, completes its growth in about 6 weeks after the sprouting of the seed. As the plants are entirely dependent upon seed for their perpetuation, their seed habits are exceptionally strong, the viability of the seed from year to year averaging considerably higher than that of the perennial plants. In spite of strong seed habits, however, there is a wider variation from year to year in the density of the stand of the early-weed stage than in any other type. This is chiefly due to the fact that there is not always ample moisture for plant life in the superficial soil layer in which the feeding roots of this consociation are located. While often variable in density, the ruderal-weed type nevertheless persists until enough organic matter has been accumulated in the soil to favor the establishment of plants of the second-weed stage.

Little forage is produced by the first-weed type. While a considerable number of species are grazed by sheep (few are eaten by cattle and practically none by horses), only a small amount of dry matter is produced. Douglas knotweed, the most abundant species, is cropped with moderate relish both by sheep and cattle and probably furnishes as much feed as all the other annuals combined. However, the ruderal-weed cover is grazed only when the herbage is succulent and tender. In view of the early maturity of the vegetation and the fact that the first-weed-stage cover affords poor protection of the

watershed, it is essential that stock permitted on this type be handled in accordance with the most approved methods. If serious erosion is to be prevented, the lands should be grazed very lightly or not at all until plants of the second-weed stage have gained a foothold.

THE EFFECT OF GRAZING ON PLANT SUCCESSION.

The grazing of live stock may, under certain conditions, either retard or promote the development of a plant cover and cause either retrogression or progressive succession.

DESTRUCTIVE GRAZING AND ITS RELATION TO EROSION.[1]

The highest grazing efficiency consists in getting the greatest possible use out of the range from year to year. Any system of grazing, therefore, which decreases the carrying capacity of the lands so that the forage production is decreased from season to season may be classed as destructive. If such a method is continued, the ground cover will be partly or wholly destroyed, a condition which is almost invariably associated with erosion.

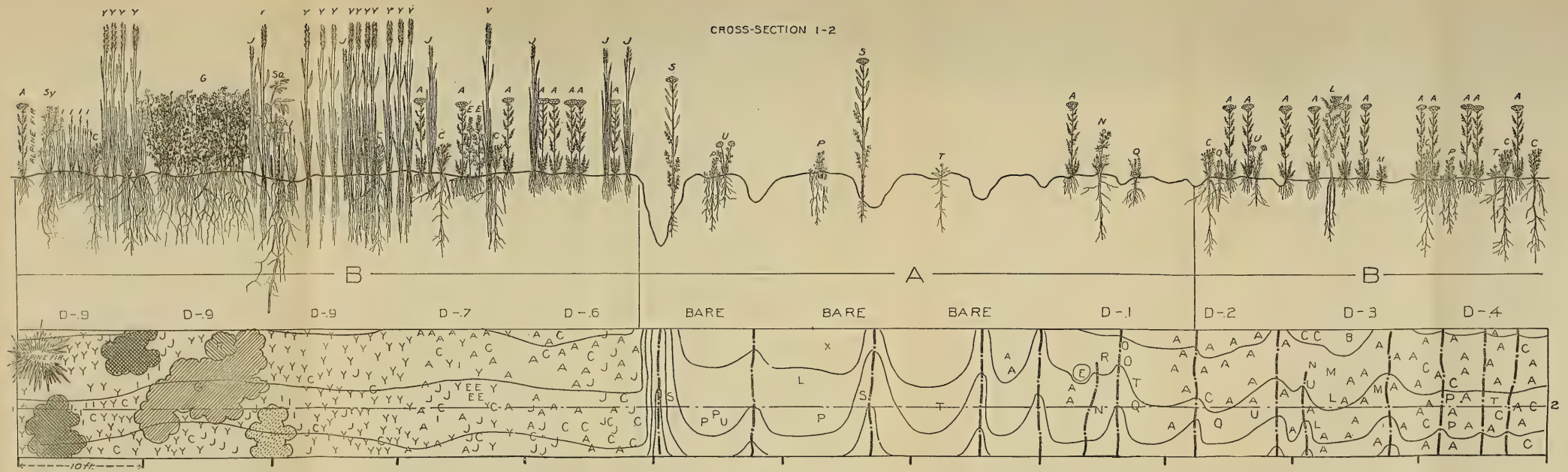
While it is probably true that the extent of surface run-off and erosion is largely determined by climate, topography, and soil, the combined influence of these factors on the high mountain grazing lands of the West is not such as to cause serious soil depletion except where the vegetative cover has been badly impaired. A typical case of overgrazing, indicating the relation of the vegetative cover to erosion, is shown in figure 21.[2] The more important facts brought out in figure 21 may be summarized as follows:

1. Where the original cover remained intact, as in section B to the extreme left in the figure, practically no erosion occurred. Partial destruction of the vegetation (section B to extreme right) was accompanied by moderate erosion, while serious destruction of the cover (section A) was associated with erosion of a most serious character.

2. The colonization on the moderately depleted areas (section B to extreme right) consists essentially of typical second-weed-stage plants, while on the very sparsely colonized blocks (section A) the vegetation is composed either of the first-weed-stage plants or of

[1] For further information as to the relation of grazing to erosion, see Sampson, Arthur W., and Weyl, Leon H., "Range Preservation and Its Relation to Erosion Control on Western Grazing Lands," U. S. Dept. of Agr. Bul. No. 675, 1918.

[2] The area represented lies at an elevation of about 10,000 feet, has a western exposure, and an average slope of approximately 11 per cent. Until 1905, when the lands came under governmental control, the range had been subject to heavy overgrazing by all classes of stock. Since 1905, the area has been subject to moderate grazing by cattle and sheep. As a result, considerable revegetation has taken place where the original cover remained more or less intact, and where little or no erosion occurred. The badly eroded areas, however, have improved relatively little in carrying capacity during the past 10 or 12 years (1905–1917) of moderate grazing, and now they furnish only a small amount of inferior forage.



A—Where original cover was destroyed by grazing.

A—Yarrow (*Achillea lanulosa*).
B—Erigeron (*Erigeron macranthus*).
C—Yellow brush (*Chrysothamnus lanceolatus*).
E—Sweet sage (*Artemisia discolor*).
G—False gooseberry (*Ribes montigenum*).
I—Spiked trisetum (*Trisetum spicatum*).
J—Small mountain porcupine grass (*Stipa minor*).
L—Low pea vine (*Lathyrus leucanthus*).
LA—Evening primrose (*Lavauxia flava*).
M—Slender-leaved collomia (*Collomia linearis*).
N—Slender cinquefoil (*Potentilla filipes*).
P—Blue foxglove (*Penstemon procerus*).
Q—Bladder pod (*Lesquerella utahensis*).
R—Mexican dock (*Rumex mexicanus*).
RI—Currant (*Ribes inebrians*).

B—Where original cover remained more or less intact.

S—Tansy mustard (*Sophia incisa*).
SO—Mountain elder (*Sambucus microbotrys*).
SY—Snowberry (*Symphoricarpos oreophilus*).
T—Dandelion (*Leontodon taraxacum*).
U—False cymopterus (*Pseudocymopterus tidestromii*).
X—Knotweed (*Polygonum aviculare*).
Y—Slender wheat grass (*Agropyron tenerum*).

D—Density. Contour interval 1 foot.

FIG. 21.—Character and density of vegetation.

species that appear very early in the succession of the second-weed stage. The blocks upon which the cover was only slightly impaired are occupied essentially by the subclimax wheat grasses.

3. The root system of the vegetation as a whole, as shown in the cross-section view of figure 21, is the sparsest and most superficial on the seriously eroded blocks, intermediate both as to depth and density on the moderately eroded areas, and deepest and most abundant on the least eroded and most highly vegetated blocks.

Chemical analyses of the soil have clearly shown that the fertility is roughly in proportion to the extent of the soil depletion, the least soil eroded being the most fertile. In these tests the samples of noneroded soil contained an average of approximately four times more organic carbon, three times more total nitrogen, and four times more total organic matter than did the eroded samples. Likewise the water-holding power in the soil samples from the noneroded blocks, when saturated, was greater by 9 per cent than in the samples from the eroded blocks.

From these facts it is evident that any system of grazing which results in the destruction of the ground cover and at the same time permits erosion to gain headway, not only immediately decreases the carrying capacity of the lands but prevents the establishment of the more permanent cover for an indefinite period—in some instances possibly for 50 years or more.[1] The translocation of the upper few inches of the surface layer of soil, with its comparatively rich impregnation of organic matter, causes the usual reversion of the vegetation to a lower successional stage, not uncommonly the first-weed stage. Under such conditions the former dominance of the subclimax species will not again appear until the original fertility of the soil has been reestablished, which is possible only after the application of many years of judicious range management. The continuance of grazing without regard for the growth requirements of the vegetation causes further soil depletion.

FORAGE PRODUCTION ON DRIVEWAYS AND BED GROUNDS.

The use year after year of established driveways and bed grounds for stock furnishes noteworthy instances of retrogressive succession. While it is true that the majority of the driveways on the National Forests were most seriously depleted before the lands came directly under the control of the Government, and that since that time many have improved somewhat in productivity, generally they support only a sparse cover of inferior transitory vegetation. Established bed grounds are usually depleted in proportion to the length of time

[1] Shantz, H. L., "Plant Succession on Abandoned Roads in Eastern Colorado," Journal of Ecology, Vol. V, No. 1: 19, 44, 1917.

they have been used. Not uncommonly they represent the most serious destruction of the plant cover that can occur on the range.

In order to determine what plant species characteristically colonize heavily on long-used driveways and bed grounds, taking into account the rate at which such areas may revegetate under different methods of management, a number of small sample plots were carefully selected for special study. Some of the selected plots have been protected from live stock by fencing; others received no protection and were subject to normal seasonal grazing.

STOCK DRIVEWAYS.

A generalized sketch of the vegetation and other features on a portion of the driveway selected for special study is shown in figure 22.[1]

While a few grasses have gained a foothold on this driveway, the ground cover is quite open and composed chiefly of a mixed stand of weeds, characteristic of the first and the second weed stage. Listed in the order of their abundance, it will be noted that Douglas knotweed, slender-leaved collomia, and tansy mustard constitute the dominant early-weed species on this portion of the driveway, as indeed they do on the driveway as a whole; tongue-leaved violet, dandelion, and low larkspur constitute the predominating late-weed-stage plants. Other typical species of the late-weed stage are chickweed, evening primrose, low pea vine, meadow rue, and plantain. The more persistent species, blue foxglove and sweet sage, have gained a foothold, but apparently conditions do not yet favor rapid colonization of these plants. In 1917 the vegetative blocks representing the unprotected driveway had a density of stand of about 0.15.[2] The protected area when fenced in 1915 was identical as to species and density with that of the outside range, but in 1917 supported a cover of approximately 0.2. This slight increment in the stand over that on the adjacent unprotected range is composed of annual and perennial weed species in equal proportions.

Much the same vegetative development occurs on another protected plot, a bisect detail of which is shown in Figure 23.[3] Of the

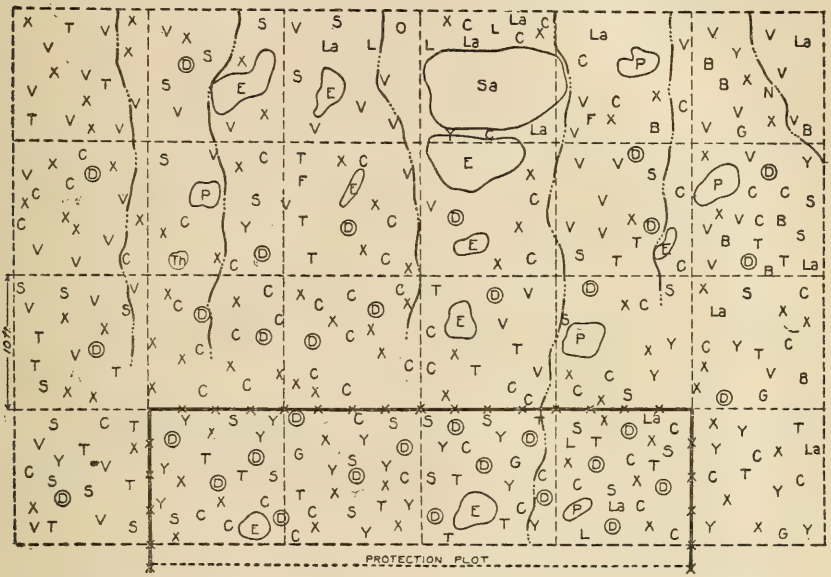
[1] The area here sketched had been so severely overgrazed at the time the lands were included within the National Forest in 1905 that practically every vestige of the herbaceous perennial vegetation had been destroyed. During the past 12 years the area has been grazed in moderation, during the main growing season, by cattle, sheep, and horses. In listing the plants it was the aim to record the species that occurred in each vegetational unit but not every individual. The relative density of the respective blocks, however, is shown.

[2] Density measurement is on the basis of ten-tenths for full cover.

[3] It is noteworthy that of the eight species that occur in the bisect all are typical either of the first or of the second weed stage, a fact which strongly substantiates the conclusion that their increase in abundance on a range in a higher stage of development would announce the waning of the higher type.

perennial plants on both of these protected plots, low larkspur has increased proportionately much more rapidly than any other; on the outside range the colonization of the low larkspur has been only moderately rapid and in proportion to that of other perennial plants.

This difference in aggressiveness of larkspur is accounted for by the fact that the unprotected range is grazed by sheep prior to seed maturity.[1] As larkspur is fairly palatable to sheep, only a small pro-



B—Large mountain brome grass (*Bromus marginatus*).
C—Slender-leaved collomia (*Collomia linearis*).
D—Low larkspur (*Delphinium menziesii*).
E—Sweet sage (*Artemisia discolor*).
F—Spiked fescue (*Festuca confines*).
L—Low pea vine (*Lathyrus leucanthus*).
La—Evening primrose (*Lavauxia flava*).
N—Chickweed (*Alsine jamesiana*).
—×—×— Fence.
P—Blue foxglove (*Pentstemon procerus*).
S—Tansy mustard (*Sophia incisa*).
Sa—Mountain elder (*Sambucus microbotrys*).
T—Dandelion (*Leontodon taraxacum*).
Th—Meadow rue (*Thalictrum fendleri*).
V—Tongue-leaved violet (*Viola linguaefolia*).
X—Douglas knotweed (*Polygonum douglasii*).
Y—Plantain (*Plantago tweedyi*).
—— . . —— Dry gully.

FIG. 22.—Character of vegetation on a formerly depleted stock driveway in process of recuperation.

portion of the seed crop is matured on the open range, whereas maximum seed production is secured on the protected area. Being small, comparatively heavy, and without special contrivances favoring distribution by wind or attachment, the seeds drop near the parent plant, where they give rise to new individuals.

Like certain other species previously discussed, low larkspur holds a more or less conspicuous place in the development of the vegetation

[1] Most larkspurs are grazed with moderate relish by sheep, and, so far as known, without serious results.

from the time of the waning of the early-weed stage to the passing of the late-weed stage; therefore, on the higher ecological types, an increase in the abundance of larkspur may be declared a reliable indicator of overgrazing.

Generally low larkspur is most conspicuous early in the development of the second-weed stage. Accordingly, on cattle range the heaviest losses from poisoning by low larkspur are apt to occur where the lands have been depleted so seriously that the vegetation is in the second-weed stage or in the first and second mixed-weed stage.

BED GROUNDS.

Although some variation is found in the vegetation of different bed grounds and adjacent lands of the region, depending chiefly on the character of the soil and the topographic features, the predominating species are generally the same where the extent of the depletion of the soil is the same.

On long-used bed grounds, where the adjacent cover is more or less intact, various distinct vegetative stages may commonly be distinguished, radiating from the bed ground proper. This is exemplified in the bed ground shown in figure 24.[1]

The main part of the bed ground (zone 1) is practically circular and covers 22 acres. Owing to the heavy use made of the bed ground each year, not a vestige of the original wheat-grass vegetation remains; indeed, even the most aggressive annual plants are for the most part lacking.

Adjacent to the bed ground proper is an irregular zone of about 85 acres. Here the colonization is composed solely of plants of the first or early weed stage. The plants are widely scattered (the density being estimated at 0.05 on a basis of ten-tenths representing full cover) and are distinctly lacking in luxuriance of growth. The species predominating in 1917, named in the order of abundance, were Douglas knotweed, Tolmie's orthocarpus, tansy mustard, tarweed, goosefoot, and androsace. Much less conspicuous were the following species: knotweed (*Polygonum aviculare*), monolepis, peppergrass, and slender-leaved collomia.[2] As already indicated, this type of cover afforded practically no grazing for any class of stock.

Zone 3 comprises approximately 215 acres, and consists of a weed cover of the early and late stages, with the early-stage species distinctly predominating. An occasional grass specimen is also seen. Here the density of the cover is estimated at 0.15, or three times that of the pure early-weed stage adjacent to the bed ground. The pre-

[1] The bed ground here represented has been used annually for several successive years by a band of about 1,400 ewes and their lambs. As a rule, the forage cropped in conjunction with the use of this camp has been grazed during the main growing season.

[2] Slender-leaved collomia is often among the first to colonize abandoned bed grounds and sometimes is a predominating species.

A, *Yarrow* (*Achillea lanulosa*).
Ar, Sweet sage (*Artemisia discolor*).

Co, Slender-leaved collomia (*Collomia linearis*).
D, Low larkspur (*Delphinium menziesii*).

Pg, Knotweed (*Polygonum aviculare*).
Pt, Plantain (*Plantago tweedyi*).

So, Tansy mustard (*Sophia incisa*).
V, Tongle-leaved violet (*Viola linguaefolia*).

FIG. 23.—Sheep driveway used annually until 1915, when protection plot was established showing character of vegetation in 1917.

dominating plants of the early-weed stage were practically identical with those reported in zone 2. Of the late-weed stage species the following were conspicuous: tongue-leaved violet, evening primrose, low pea vine, Mexican dock, butterweed, plantain, sneezeweed, and false cymopterus. These species, it will be recalled, have been listed as characteristic forerunners of the more permanent species of the late-

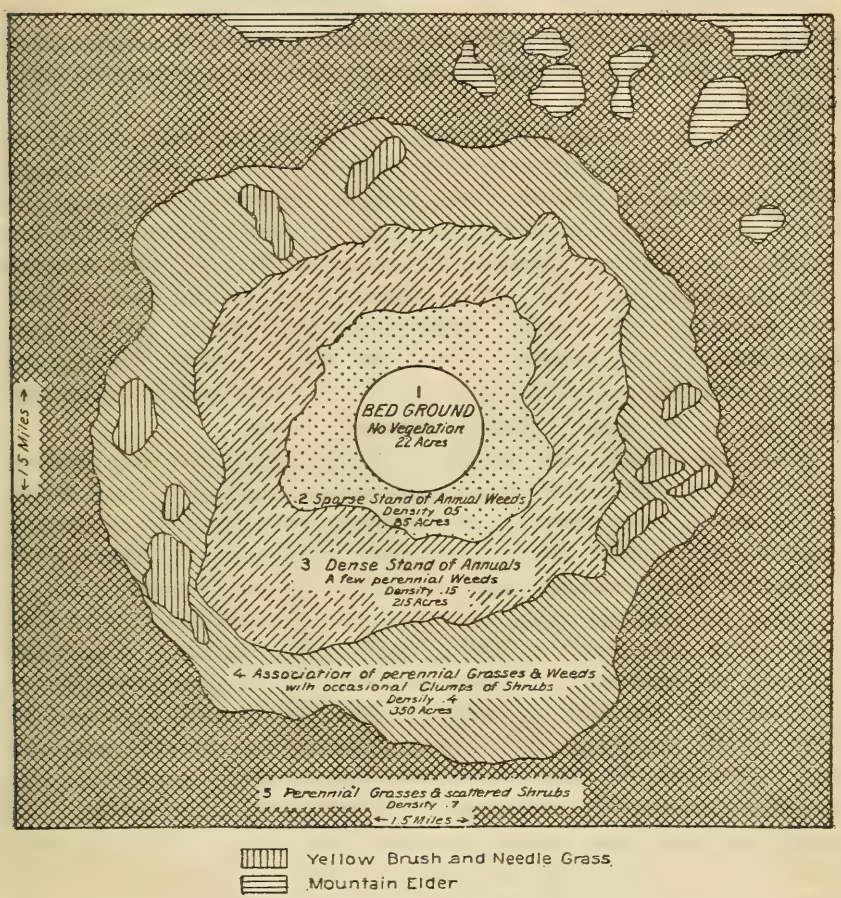


FIG. 24.—Bed ground used for several successive years, showing zones of vegetation and range depletion.

weed stage, a fact which is strongly substantiated in this instance. While they are distinctly second-weed stage species, they may be classed as transitional successionally between the early-weed stage and the second-weed stage when the latter is characterized by turfed plants, such as blue foxglove, sweet sage, and yarrow. Only a small portion of the herbage in this belt is relished by sheep. The feed is low in quality and unless cropped early in the season has practically no forage value.

The fourth zone, a mixed cover of perennial grasses and weeds, comprises an area of approximately 350 acres. The density of this stand is 0.4. The cover as a whole is dominated by plants of the second-weed stage, notably sweet sage and yarrow, though here and there the fescues and the brome grasses have gained dominion over the soil. A few well-defined areas of from a few to many acres are dominated by small mountain porcupine grass and yellow brush. When the density of the cover is considered, this belt affords fairly good feed for sheep; it can not be cropped advantageously by cattle and horses.

The fifth type, composed essentially of a grass cover and an occasional clump of mountain elder, has a density of 0.7. Slender wheat grass and blue bunch wheat grass are the predominating species, while small mountain porcupine grass, several species of the blue grasses, and a few specimens of fescue and of brome grasses occur in varying abundance. In adition, there is a scattered stand of late-weed-stage species, of which sweet sage and yarrow are the most abundant. This type affords good feed for all classes of stock; and the highest grazing efficiency on it may be expected from common use; that is, the grazing both of cattle and sheep.

From the viewpoint of forage production alone, the data pertaining to the use year after year of this established bed ground show:[1] (1) There is practically a total sacrifice of 107 acres, composing zones 1 and 2, which formerly supported at least a 0.7 cover of the choicest of feed—an area large enough to support about 65 sheep, or 16 cows, per summer season of 100 days; (2) there is a belt of 215 acres which, assuming that half of the present vegetation is palatable to stock, may now carry 16 sheep or 4 cows, but formerly would have taken care of 130 sheep, or about 32 cows; (3) there is a zone of 350 acres which, assuming that three-fourths of the cover is palatable, may now carry 105 sheep or 26 cows, but formerly would have supported approximately 210 sheep or 52 cows. In other words, if the range had been used under the bedding-out system, and the lands maintained properly, the data indicate that no less than 280 more sheep, or 70 more cattle, could now be taken care of on this part of the allotment alone. Assuming that there are other similar destructively used bed grounds on the allotment, it is evident that its present car-

[1] In calculating the carrying capacity of the vegetative belts, it is assumed that the entire area originally had a cover similar in density to that of the contiguous perennial grass range at the present time. The writer believes this assumption to be conservative, if not too low, in view of the fact that the soil is deep throughout. Sheep would not completely utilize the former wheat-grass cover with its small amount of weed forage. Cattle, on the other hand, would use little of the weeds. For this reason a deduction of about 14 per cent is made for wastage in utilization of the original cover to be consistent with the deductions for low palatability in the present cover. Since the former wheat-grass cover was undoubtedly much denser prior to the establishment of the bed ground than the present wheat-grass cover on certain portions, no deductions are made for waste of forage in calculating the former carrying capacity of the area.

B, Large mountain brome grass (*Bromus marginatus*).
Ch, Lamb's-quarter (*Chenopodium album*).
H, Mountain squirrel tail (*Hordeum nodosum*).
La, Evening primrose (*Lavauxia flava*).
Pg, Douglas knotweed (*Polygonum douglasii*).
R, Mexican dock (*Rumex mexicanus*).
Pl, Plantain (*Plantago tweedyi*).
So, Tansy mustard (*Sophia incisa*).
V, Tongue-leaved violet (*Viola linguaefolia*).

FIG. 25.—Old denuded bed ground abandoned in 1912, showing character of vegetation in 1917.

rying capacity is far below normal because of the use of established bed grounds.

Contrary to the consensus of opinion among stockmen and others, the reduction in the forage crop on bed grounds can not be classed as temporary. The belief prevails that the large amount of fertilizer contained in the soil on the main part of a bed ground, and on the lands adjacent thereto, will favor the most rapid and thorough revegetation. Experimentation does not substantiate this opinion.

In the plot shown in figure 25[1] after 5 years of protection against grazing, only a sparse stand of vegetation had gained a foothold, the cover being composed chiefly of species of the early-weed stage which are distinctly transitory, notably Douglas knotweed, goosefoot or lamb's-quarters, and tansy mustard, in addition to a few species which have been shown to be forerunners of the more permanent second-stage cover. In addition, the average height of the different species, as well as the depth of their root systems, was considerably less than over the range generally. This delayed colonization is accounted for by the physical rather than by the chemical condition of the soil. To be sure, the abnormally large amount of available nitrogen and other salts in the soil on bed grounds has a tendency to promote the height growth of the plant somewhat at the expense of seed production; but since a large amount of seed is deposited annually on the bed ground, it is not probable that the organic deposits in the soil have any appreciable effect on the rate of the invasion or the extent of the establishment of the vegetation. It is well known, on the other hand, that the soil on bed grounds is packed exceedingly hard. So firmly packed is the surface on long-used bed grounds that nearly all the superficial seed either fails to germinate or the seedling dies as soon as the food stored in the seed is exhausted. As a rule, the radicle of the germinating seed fails to extend itself into the soil to a depth great enough to reach adequate available moisture. Containing, as the local soil does, a large percentage of clay, the trampling, especially in wet weather, tends to produce the single-grain soil structure, which is most unfavorable to establishment and growth of vegetation.

SUCCESSION ON MODERATELY DEPLETED RANGE GRAZED ANNUALLY PRIOR TO SEED MATURITY COMPARED WITH SUCCESSION ON SIMILAR RANGE PROTECTED YEARLONG.

In certain stages of premature grazing or overstocking, the more hardy and persistent perennial plants may become so weakened that all reproduction is temporarily arrested. Long before this condi-

[1] The plot of which figure 25 is typical was fenced against grazing in 1912, prior to which it had been heavily used as a bed ground for several successive years. The bisect here shown traverses the plot and represents a strip 3 inches wide and 16 feet long.

tion has manifested itself, however, the less hardy palatable plants have been killed. In such serious instances of physiological weakness, the aerial development of the remaining vegetation is often well-nigh lacking; yet the buds at the crowns of the plants, as well as a considerable portion of the root systems, may survive. So long as the factor disturbing the physiological balance of the vegetation persists, most of the buds at the plant's crown remain dormant, only an occasional aerial shoot being produced to elaborate food and nourish the plant. Where a considerable portion of the vegetation is alive, yearlong protection, or grazing after seed maturity, will greatly promote revegetation. In figure 26 is indicated the effect of protecting yearlong a moderately depleted range. The unprotected area represented has been grazed moderately by sheep and cattle before seed maturity each year during the period of the test, and corresponds to the grazing practice in vogue prior to the experiment. When the protected areas shown in the figure were fenced in 1913, the vegetation appeared identical with that outside in character, density, and vigor.[1] The difference in 1917 in these particulars is summarized in Table 7.

TABLE 7.—*Comparative height and density of vegetation on plot protected from grazing for five successive years and on unprotected adjacent range grazed annually by sheep, usually well in advance of seed maturity.*[1]

Plant.	Density per square foot.			Relative height (physiological index).		
	On protected plot.	On open range.	Per cent difference.	On protected plot.	On open range.	Per cent difference.
Yarrow (*Archillea lanulosa*)	45.6	28.2	38	1.47	0.85	42
Slender wheat grass (*Agropyron tenerum*)	1.6	1.4	12	3.06	1.20	61
Androsace (*Androsace diffusa*)	.....	.7	.....	.....	.....	.....
Sweet sage (*Artemisia discolor*)	3.2	.....	100	1.20	.....	.....
Aster (*Aster frondeus*)	45.6	16.9	63	1.90	1.03	46
Tall larkspur (*Delphinium barbeyi*)	.8	1.4	[2] 75	5.20	4.40	15
Low pea vine (*Lathyrus leucanthus*)	3.2	2.1	34	1.70	1.20	29
Evening primrose (*Lavauxia flava*)	.....	5.6	.....	.....	.....	.....
Douglas knotweed (*Polygonum douglasii*)	.....	12.7	.....	.....	1.20	.....
Plantain (*Plantago tweedyi*)	.8	1.4	[2] 75	.....	.....	.....
Tansy mustard (*Sophia incisa*)	4.8	4.9	[2] 2	2.82	2.13	24
Small mountain porcupine grass (*Stipa minor*)	12.0	4.2	65	2.56	1.18	54
Dandelion (*Leontodon taraxacum*)	7.2	3.5	51	.....	.....	.....
Meadow rue (*Thalictrum fendleri*)	4.0	0.8	80	2.92	2.92	0
Spiked trisetum (*Trisetum spicatum*)	2.4	2.8	[2] 17	1.95	0.96	51
Tongue-leaved violet (*Viola linguaefolia*)	4.0	1.4	65	.....	.....	.....

[1] The figures here given were compiled from a bisect 16 feet long and 1 inch wide and outside of the protection plot. Owing to the unwieldiness of such a sketch, only half of its length is shown in figure 26.
[2] Indicates more individuals per square foot on the unprotected range than on the protected range.

In the density of the vegetation per square foot, the difference in the percentage figures for the highly palatable perennial plants is

[1] Comparative average height growth of the different species on the fenced and unfenced areas is here used as an index of physiological vigor, of which it is believed to be a reliable criterion.

distinctly in favor of the protected plot. Thus, for instance, yarrow shows a difference of 38 per cent in favor of the protected plot; slender wheat grass, 12 per cent; sweet sage, 100 per cent; small mountain porcupine grass, 63 per cent; and dandelion, 51 per cent. In four species the greatest density occurs on the unprotected area. In the case of at least one plant, tall larkspur, the result is apparently accidental, as the plants concerned are old and thoroughly established, so that it is not probable that they have invaded the area since the establishment of the plot. Two of the species, plantain and tansy mustard, rapidly colonize the more exposed soils, so that their greater rate of increment on the outside range, as compared with that on the better vegetated protected area, is not alogether surprising.

The contrast in the relative height growth of the different species is strikingly in favor of the protected area, the percentages being greater in all but one instance. The exception is meadow rue, a plant which locally is grazed practically not at all, hence is as vigorous physiologically on the unprotected area as on the protected plot. Careful analysis of the data as to relative height shows that the percentage difference is roughly in proportion to the palatability of the plant, as would be expected. According to observations, the difference in height growth corresponds in general to the difference in seed production, the larger seed crop being produced on the protected area. This physiological response, as a result of complete rest of a cover weakened by injudicious grazing, is identical with the vigorous response of a similarly weakened vegetation when the deferred and rotation system of grazing is applied.[1] In either treatment practically complete physiological recovery results in about three years.

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[1] Where a good deal of the original forage cover has been destroyed and the remaining plants weakened from overstocking or too early grazing, the deferred and rotation grazing system, if strictly applied, will soon result in revegetation.

In applying the deferred system of grazing, such portion of the range as is consistent with the welfare of the range as a whole is reserved for cropping until after the maturity of the seed of the main forage species. Upon the maturity of the seed, the range is grazed closely, but not destructively, by the stock allotted to the lands. The following year, owing to the large proportion of seedlings destroyed, especially on areas grazed early in the season, the forage is not to be cropped until another season's seed has been produced. If, after the production of two seed crops of the choice native forage species, an ample number of seedling plants have been established, a second area in need of seeding is selected, and the tract upon which grazing was previously deferred is then grazed before seed maturity. This same plan is continued season after season, alternating the deferred grazing first on the one area and then on another, until the entire range has rejuvenated. After the vegetative cover has been established, however, the deferred grazing is alternated or rotated from one portion of the range to another in order to permit the formation and distribution of an occasional seed crop by means of which the old plants may be replaced. In this way the range is brought back and maintained in its maximum state of productivity without the loss of a season's forage crop during the period required for revegetation. For full discussion of this subject see: Sampson, Arthur W., "Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation." Jour. Agri. Research, vol. 3, No. 2, 1914. Sampson, Arthur W., "Range Improvement by Deferred and Rotation Grazing." U. S. Dept. of Agr. Bul. No. 34, 1913.

Owing to the stock working the seed into the ground as the mature herbage is grazed, better reproduction from seed is procured on the area upon which the grazing is deferred than on that protected from grazing yearlong. The vegetative reproduction, on the other hand, is the same in the case of either treatment.

Obviously, the increase in density that occurred on the protected area here shown can not be termed true succession. A large number of running rootstocks of such plants as yarrow, sweet sage, low pea vine, and the like, as well as the weakened inconspicuous tufts of the grasses, existed before the stock was excluded, and the shoots began to appear as soon as sufficient food had been elaborated to stimulate the buds to growth. Therefore, the practice of protecting the lands from stock throughout the year will result in quite as rapid revegetation by vegetative means as will deferred grazing. Reproduction from seed, especially in large-seeded species, however, is much more vigorous on areas where the grazing is deferred until the seed crop has ripened. Hence deferred grazing has all of the advantages of total protection and none of the disadvantages, such, for example, as low or negative reproduction from seed, and waste of forage during the period required for revegetation.

JUDICIOUS GRAZING.

In any well-planned method of grazing designed to handle the lands as permanent grazing areas, two objects must be kept in mind. One is the cropping of the herbage at a time in the season when growth and reproduction will be interfered with as little as possible. The other is the utilization of the forage crop when it is most needed and when the herbage is palatable and nutritious.

At first thought it would appear that the requirements of the vegetation and the requirements of the stock are rather antagonistic, but if proper precautions are taken, this need not be the case. Few plants, even when grazed closely, are appreciably weakened by being grazed early in the season,[1] let us say once in 3 or 4 years. Repeated close early grazing, on the other hand, soon destroys the cover. Through the application of the deferred-and-rotation grazing system, which provides for the cropping of a portion of the range early in the season only every third or fourth year, the vegetation will retain its vitality almost as well as when not utilized at all, provided, of course, that the number of stock carried is correctly estimated. Hence judicious grazing on a well-vegetated area disturbs the cover only to a slight extent.

[1] Early grazing may be defined as cropping of the herbage between the time that the flower stalk is "in the boot" or sheath, that is, on the verge of appearing, and the time of completion of the fertilization of the flowers, approximately between 2 and 4 weeks after growth has begun.

SUMMARY OF THE EFFECT OF GRAZING ON PLANT SUCCESSION ON THE RANGE.

Grazing may cause either progressive or retrogressive succession, depending chiefly upon the closeness with which the herbage is grazed annually and the time when it is cropped. If the forage crop is grazed closely before seed maturity each year, the general trend of the succesion will be retrogressive; if, on the other hand, the crop is maintained in a high state of vigor at all times and then grazed after seed maturity every third or fourth year or so, the succession will be progressive, or, if there is virtually a full ground cover, a maximum density will be maintained. Premature and too close grazing not only favor retrogressive succession and ultimately the destruction of the vegetative cover, but also tend to impair the fertility of the soil through the devastating effect of erosion. The seriousness of the depletion of the soil, provided the lands are judiciously managed, will determine chiefly the time required for thorough revegetation. Therefore, the longer retrogressive succession is permitted to operate the longer will be the time required for the reestablishment of the forage cover. The final outcome of vegetative degeneration and erosion is the translocation of the entire soil formation and the exposure of the underlying rocks. As a rule, however, only the rich surface layer of soil is removed, a condition which favors the immediate establishment of a cover of the first-weed-stage plants.

The continued hard use of established live-stock driveways and bed grounds favors the destruction of the more stable type of vegetation and the establishment of plants of the early and late weed stages. These species afford highly reliable indicators of overgrazing and thus show clearly what lands are being depleted or soon will be in an inferior state of productivity provided the disturbing factor is not corrected. Obviously, therefore, the use of established driveways and bed grounds, especially the latter, tends greatly to decrease the carrying capacity of the lands.

Owing to the hard packing of the soil, these much trampled areas revegetate slowly. The succession on bed grounds, for instance, is similar to that on depleted lands, the revegetation beginning with the early-weed stage and progressing through the intermediate covers to the subclimax.

In the way of revegetation, it is evident that yearlong protection of bed grounds and other depleted lands from live stock tends to hasten vegetative or asexual reproduction no more than when the grazing is deferred until after seed maturity. Deferred grazing, on the other hand, has the additional distinct advantage over yearlong protection of permitting the forage crop to be grazed during the restocking period, and of procuring a maximum stand of seedling

plants as a result of the animals planting the seed as they graze. Accordingly, progressive succession is especially active where the deferred-and-rotation grazing system is strictly applied.

GENERAL SUMMARY.

1. The carrying capacity of a large portion of the millions of acres of western ranges has been materially decreased as a result of too early grazing, overstocking, and other faulty management. One of the most serious handicaps has been lack of means of recognizing overgrazing in its early or incipient stages, which has carried with it inability to correct the factor causing the damage before the carrying capacity of the range was more or less seriously depleted.

2. In deciding upon the lands especially in need of improvement in the past, stockmen and forest officers regulating grazing have relied chiefly upon the general abundance and luxuriance of the forage supply and upon the condition of the stock grazed. By these general observations, however, it is not possible to recognize overgrazing before a large proportion of the plants have been killed.

3. The most rational and reliable way of recognizing the incipient destruction of the forage supply is to note the replacement of one type of plant cover by another, a phenomenon which is usually much in evidence on lands used for the grazing of live stock.

4. In tracing the succession of plant life from the consolidated rock to a well-disintegrated, fertile soil several fairly distinct cover stages are recognized. These stages may be grouped as follows: (1) The algæ-lichen type, the pioneer stage; (2) the lichen-moss type with its sparse stand of annual herbs, the transition stage; (3) the ruderal-weed type or cover of annual plants with a scattered stand of short-lived perennials, the first-weed stage; (4) perennial herbs, chiefly weeds, the second-weed stage; and (5) the long-lived perennial grasses, known as the subclimax, or under some conditions, the climax type.

5. In order to observe the principles of succession in the building up as well as in the deterioration of the range, special studies were initiated on the high summer range of the Wasatch Mountains in central Utah. After a careful survey of the vegetation, four major consociations were recognized, namely, the wheat-grass, the porcupine-grass-yellow-brush, the foxglove-sweet-sage-yarrow, and the ruderal-early-weed.

THE WHEAT-GRASS CONSOCIATION.

6. The wheat-grass consociation is the subclimax or highest forage type successionally. The turfed wheat-grass cover binds the soil so firmly as largely to prevent the invasion and establishment of other

plants. The bunched wheat-grass areas, on the other hand, are seldom pure in stand, and plants other than grasses usually occupy the soil space between the tufts. The nongrasses occur in varying density, depending chiefly upon the available soil water content.

7. The root-absorbing surface of the densely turfed wheat grasses is relatively superficial, the greater proportion of the roots being confined to the upper 8 inches of soil. The roots of the bunched species typically extend to a depth of 3 feet or more, hence their moisture supply is largely gathered well below the depth at which the turfed species obtain theirs.

8. Precipitation percolates so slowly through the matlike surface of the turfed wheat-grass area that only a small portion of the rainfall, especially that which comes during the growing season, penetrates beyond the lower depths of the sod. Accordingly, other plants, especially deep-rooted species, fail to become established in competition with the turfed wheat grasses.

9. Precipitation percolates deeply on the rather exposed soils of the bunch-grass areas, and as a consequence both deep-rooted and shallow-rooted species, chiefly other than grasses, are commonly found on bunch wheat-grass areas.

11. When a stand of bunch wheat grass is opened up there is an some similar factor but not so as seriously to decrease the fertility of the soil, the precipitation naturally percolates to a much greater depth than where the turf remains intact. There follows an invasion of certain deep-rooted species, the most typical and persistent of which is yellow brush (*Chrysothamnus lanceolatus*). As the wheat-grass cover closes in about the yellow-brush plants, however, regardless of their luxuriance of growth and root development, they are killed. This is due to the desiccation of the soil below the shallow roots of the grass.

11. When a stand of bunch wheat-grass is opened up there is an increase in the density of other plant species. This secondary cover is rather transitory both as to species and density.

12. In terms of the amount of dry matter produced per unit of surface, the turfed wheat-grass areas rank first, but owing to small wheat grass (*Agropyron dasystachyum*), the most conspicuous turfed species, maturing somewhat earlier than the bunch grasses and at the same time becoming less palatable when mature than the bunch grasses, the turfed wheat-grass areas afford little, if any, more forage than do the bunched wheat-grass areas.

13. The wheat-grass type is the most permanent of any and withstands heavy grazing better than any other. Since the turfed wheat grasses typically form a pure stand, this type of vegetation is better suited for cattle and horses than for sheep. The virgin bunch-grass lands, with their "combination" or mixed forage cover, while

probably more fully utilized by cattle and horses than by sheep, are better suited for the grazing of sheep than the turfed wheat-grass areas. The grazing both of cattle and sheep on the bunch-grass lands, as well as on the opened-up stands of the turfed areas, insures the maximum economic use of the entire forage crop.

THE PORCUPINE-GRASS-YELLOW-BRUSH CONSOCIATION.

14. The small-mountain-porcupine-grass and yellow-brush cover is the second highest and the most stable forage type. Accordingly, porcupine grass and yellow brush are among the first perennial plants to occupy wheat-grass areas where unfavorable conditions have killed out the wheat-grass cover but where the soil has not been depleted so much as to favor the establishment of a pure or predominating weed type.

15. Because of the exposure of a considerable portion of the soil surface, precipitation readily percolates into the soil, reaching to or beyond a depth corresponding to the lower extension of the deep-rooted species. Accordingly, an admixture of shallow-rooted and deep-rooted species is characteristic of this consociation. The water-holding capacity of the soil, particularly the upper foot or so, is less in this than in the wheat-grass cover.

16. In the higher development of the porcupine-grass and yellow-brush cover a scattered stand of wheat grasses, and usually a conspicuous presence of blue grasses, and not uncommonly of fescues, is characteristic, though these plants are never dominant. In the lower or earlier development, the brome grasses, and not uncommonly the fescues, in association with numerous nongrasslike perennials, are conspicuous. The higher development is further characterized by fewer weed or nongrasslike species than the lower development.

17. Small mountain porcupine grass, like the majority of the blue grasses and fescues, obtains its moisture supply chiefly from the first foot of soil. Yellow brush and other deep-rooted species, such as loco and wild bean, extend their roots about three or four times as deep. Many plants are present whose root systems are intermediate in length, so that the available water supply from the surface to a depth of 3 feet or more is rather uniformly exhausted as the season advances.

18. The most reliable indication of the presence of conditions adverse to the perpetuation and maintenance of the porcupine-grass-yellow-brush cover, including the typical associated species, is the replacement of one or both of the dominants by aggressive nongrasslike plants. Where the depletion of the soil is gradual and not too severe, blue foxglove, sweet sage, and yarrow are the first to gain dominion over the soil, the increase in these species being associated with an increase in brome grass, and in some cases in fescues.

19. A reliable indication pointing toward the maintenance, or the progressive development of this cover, is an increasing density and luxuriance of growth of certain blue grasses, and in some instances fescues, and a decreasing stand of the brome grasses, and under certain conditions of yellow brush and other deep-rooted species.

20. With its large variety of palatable grasses and other plants this consociation is probably second to none in forage value, all classes of stock considered.

21. In general the highest possible development of this consociation affords the most nutritious forage cover, and will probably support more stock than will any other stage of plant development. It is a mixed grass-and-weed type, with the grasses distinctly predominating, and the highest grazing efficiency is obtained through "combination" or "common-use" grazing, that is, the grazing of cattle, sheep, and horses.

THE FOXGLOVE-SWEET-SAGE-YARROW CONSOCIATION.

22. Where conditions on the porcupine-grass-yellow-brush cover are such as slightly to decrease the fertility and water-holding power of the soil, blue foxglove, sweet sage, and yarrow, the most characteristic species of the second-weed stage, are among the first plants to establish themselves. Where the fertility and water absorptive capacity of the soil are seriously impaired, porcupine-grass-yellow-brush cover is succeeded by annual plants characteristic of the early or first weed stage.

23. Generally the invasional activity of the succeeding late-weed-stage plants is most vigorous shortly after the destruction of the grass-brush cover.

24. A large number of species, including some grasses, are associated with blue foxglove, sweet sage, and yarrow, but they seldom, if ever, occur as dominants. Like the dominant plants, the secondary species are moderately deeply rooted, the water supply being drawn very largely from the upper 2 feet of soil.

25. Blue foxglove, sweet sage, and yarrow reproduce both by seed and by vegetative means, the latter method being so active that the cover characteristically forms a somewhat loose, matlike surface. The seed habits are only moderately strong, yet invasion is fairly active under favorable conditions of germination and growth. Seedling plants as a rule do not produce either fertile seeds, or many shoots from the rootstocks, until the third year of growth.

26. Low pea vine, evening primrose, false cymopterus, Mexican dock, and tongue-leaved violet are the most reliable indicators of the waning of the more permanent and typical second-weed-stage cover. With the exception of pea vine the regeneration of these species is

entirely dependent upon seed. The seed crop is relatively high in viability. However, if the factor detrimental to progressive development of the vegetation is not corrected, these relatively short-lived perennials will sooner or later be superseded by plants of the first-weed stage.

27. The profusion of weedy or nongrasslike plants and the limited occurrence of grasses render the second-weed stage much better suited for sheep than for cattle and horses.

28. The carrying capacity of the second-weed-stage type, acre for acre, is very much less, regardless of the class of stock grazed, than of the porcupine-grass-yellow-brush cover. In addition, a less solid fat is produced.

29. Sheep make rapid gains on the second-weed-stage type early in the season when the herbage is succulent and tender. Cattle and horses, on the other hand, little more than maintain their weight even though the lands are lightly stocked. The vegetation matures early, after which the leafage is largely unpalatable to stock, and the herbage of many species is largely lost through the destructive effect of frost. Therefore the lands are of little value for grazing unless cropped early in the season.

THE RUDERAL-EARLY-WEED CONSOCIATION.

30. On lands whose soils have been so seriously impaired that available water is similar in amount to that held by relatively newly formed soils recently invaded by herbaceous plants, the vegetation consists essentially of annual species characteristic of the first or early weed stage.

31. The most typical and abundant species of the first-weed stage are goosefoot or lamb's-quarters, slender-leaved collomia, tarweed, Tolmie's orthocarpus, Douglas knotweed, and tansy mustard. Numerous less abundant species are associated with these.

32. The seed habits of ruderal-weed plants are strong, the viability of the seed crop averaging considerably higher than that of the perennial species.

33. Because of the entire dependence of the plants on seed for their regeneration and the fact that the conditions of the season are not always favorable to seed production or germination, there is wider variation in the density of the stand of the first-weed-stage cover from year to year than in that of any other consociation.

34. Owing to the low fertility of the soil characteristic of the first-weed stage it contains less available moisture than soil of the higher ecological types. This tends to hold the development of the vegetation in check. At the same time plants grown on inferior soils of this kind require appreciably more water for the production of a

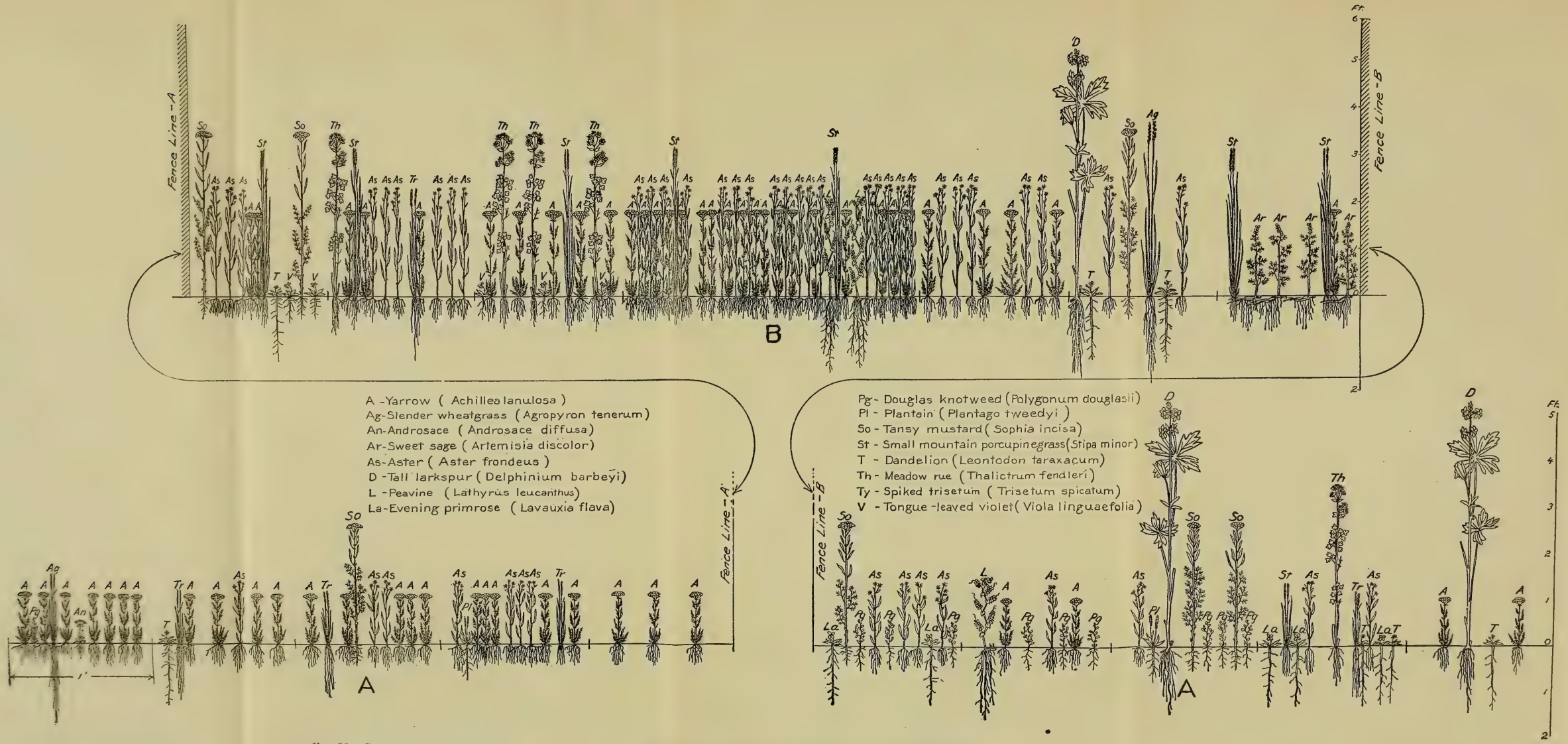

FIG. 26.—Comparative vegetative cover on range (A) grazed annually by sheep prior to seed maturity, and on plot (B) protected from grazing for five successive years, 1913–1917.

given unit of dry matter than those grown on more fertile soils. This accounts for the colonization of the badly depleted soil by shallow-rooted, early-maturing, annual vegetation, and the practical exclusion of the deeper-rooted, later-maturing, perennial species.

35. The further depletion of the soil tends to decrease the density of the stand and the luxuriance of growth of the individual specimens. If the depletion is continued until the underlying rocks are exposed, the pioneer stage of plant life—algæ and lichens—again comes into evidence.

36. A considerable number of the ruderal-weed plants are palatable to sheep, a few are grazed by cattle, and a very few by horses. Douglas knotweed, the most abundant species, is fairly palatable to sheep, and probably furnishes as much forage as, if not more than all the rest of the annuals put together. The carrying capacity of the ruderal-weed consociation is exceedingly low, and affords grazing only when the herbage is green and succulent.

37. Because of the early-maturing qualities of the vegetation and the fact that the first-weed-stage cover affords poor protection of the watershed, only the very lightest grazing should be permitted on this type. The safest plan is to exclude stock until the cover has increased appreciably.

THE EFFECT OF GRAZING ON RANGE PLANT SUCCESSION.

38. Grazing may cause either progressive or retrogressive succession, depending chiefly upon the closeness with which the herbage is grazed annually and the time of grazing. Grazing year after year before seed maturity causes retrogressive succession, while grazing every 3 or 4 years or so after seed maturity promotes progressive succession.

39. Overgrazing year after year results not only in the destruction of the ground cover, after which erosion is apt to occur, but robs the soil of its fertility and producing capacity.

40. The rate and character of the colonization of an eroded or otherwise depleted area is normally determined by the degree of soil devastation. The longer retrogressive succession continues, therefore, the more serious is the depletion of the soil and the longer is the time required to reestablish a good ground cover. The ultimate result of continued serious erosion is the exposure of the underlying rock formation.

41. The continued use of stock driveways and bed grounds results practically in complete destruction of the subclimax plant cover, thus favoring the establishment of plants of lower successional stages. The species constituting the cover from time to time afford reliable indicators of overgrazing and inferior states of soil productivity.

42. The use of established driveways and bed grounds, especially the latter, tends materially to decrease the carrying capacity of the lands. Owing to the packing of the soil by the animals, these areas revegetate slowly, the colonization usually starting with species of the early-weed stage.

43. Yearlong protection of driveways and bed grounds, as well as of other sparsely vegetated lands, tends to promote a sexual reproduction no more than deferring the grazing until after seed maturity. Deferred grazing has all the advantages of yearlong protection and none of the disadvantages, such, for example, as low or negative reproduction from seed and waste of forage during the period required for revegetation.

44. Judicious grazing tends to maintain a normal cover of vegetation, while on lands where the stand is sparse, there is a tendency toward the promotion of an upward succession leading to the ultimate establishment of the subclimax species. Progressive succession is particularly active where the deferred and rotation grazing system is strictly applied.

COMPARATIVE FORAGE VALUE.

45. The grazing value of the vegetative covers is essentially determined by the stage of the succession. Locally, and indeed generally, the carrying capacity and forage value are the highest where the cover represents a stage in close proximity to the herbaceous climax and lowest in the type most remote from the climax.

46. The most dry matter per unit of surface is produced in the wheat-grass cover, but the amount is only slightly greater than in the mixed grass-and-weed cover of which porcupine grass and yellow brush are characteristic. By far the least dry matter is found on the ruderal-weed cover, while the amount produced on the second-weed-stage type averages considerably less than on the mixed grass-and-weed type. All classes of stock considered, the porcupine-grass-yellow-brush cover produces more palatable dry matter than any other. For horses and cattle alone, more palatable dry matter is produced on the wheat-grass consociation. Accordingly, virgin stands of wheat grass afford the highest grazing efficiency and will give the biggest returns when cropped by cattle or by cattle and horses; the mixed grass-and-weed type when utilized by cattle, horses, and sheep; and the weed type, if composed either of plants of the first or of the second weed stage, when utilized by sheep alone. Except in practically a pure-weed type or a pure-grass type, the common use of the lands by the various grazing animals is generally justified. As a rule, when the most stable grass type is cropped by cattle and horses alone, it is soon sufficiently opened up to permit the establishment of at least a moderate proportion of weed plants, most of which

are highly palatable to sheep but which may be grazed little or not at all by cattle and horses. Likewise a weed cover grazed exclusively by sheep will sooner or later change to the grass stage.

INDICATORS AND THEIR USE.

The data in this bulletin justify the conclusion that the character of the native vegetation can be used as a reliable indicator of the condition of the range and of the effect of a given method of grazing on the plant cover.

The plant indicators signifying the waning of the wheat-grass cover are essentially porcupine grass and yellow brush; the retrogression of the porcupine-grass-yellow-brush cover is indicated by species of the second-weed stage of which blue foxglove, sweet sage, and yarrow are the most characteristic; the giving way of the second-weed-stage cover, here recognized by blue foxglove, sweet sage, and yarrow, is indicated by the appearance of low pea vine, evening primrose, false cymopterus, Mexican dock, and tongue-leaved violet, in addition to several species of first-weed-stage plants of which goosefoot, slender-leaved collomia, tarweed, Tolmie's orthocarpus, and Douglas knotweed are typical; and the recession or destruction of the first or early weed stage is marked, first, by the thinning out and decrease in the luxuriance of growth of the annual species, and, ultimately, by the erosion of the soil to the extent of exposing the underlying rock and destroying the holdfast for herbaceous vegetation, thus favoring the reappearance of lichens and algæ of the initial or pioneer stage.

APPLICATION OF PLANT SUCCESSION TO RANGE MANAGEMENT.

The species that are increasing appreciably on the range invariably reveal one of two stories. If the invading plants are lower in the succession than the predominating vegetation, the range is being utilized unwisely in one or more respects. If the incoming vegetation is somewhat higher successionally than the type as a whole, improvement under the management in vogue is sure to follow. Where the negative indicators are crowding out the more permanent and desirable species, remedial measures should be adopted with a minimum loss of time.

Since, as pointed out, range depletion is due chiefly to too early cropping or to overgrazing, the application of the deferred-and-rotation grazing system, coupled with a correct estimate of the carrying capacity of the range, may be relied upon fully to revegetate the lands where enough plants of desirable species are found for seed production. Areas in the first-weed stage, in the absence of desirable forage plants, should not be included in the general plan of deferred

grazing. Ranges that have been so destructively used as to support chiefly annual vegetation, can not be grazed without further deterioration. Such areas should be entirely closed to stock until the cover is clearly composed of plants of the second-weed stage. Strict application of the deferred grazing system should be applied on areas in the second-weed stage and the practice should be continued until the porcupine-grass-yellow-brush consociation has attained its maximum productivity. After that the deferred grazing plan should be rotated so that each part of the allotment is grazed after seed maturity at least once every 4 or 5 years. In general, there is little or no justification for handling the lands so as to maintain a more or less pure wheat-grass cover. If a good forage crop is to be maintained, however, the practice of using established bed grounds, of too close herding, the excessive use of dogs, and other practices which tend to destroy the vegetation must be avoided as far as possible.

In using the plant indicators as a guide to determine whether or not the range is in need of a change in the management it is well to adopt some definite means of ascertaining the changes that are taking place in the plant cover. While carefully selected plots, the vegetation of which is accurately mapped, are desirable, a careful systematic ocular estimate of the composition and density of the vegetation will suffice in practice. This can be made in various ways. A reliable method, however, is to select carefully some four or five typical areas over the allotment and lay out a plot, let us say, of 2 square rods on each area. After securely staking and tying in the plot to insure its relocation in future, list the chief indicator species as well as the most important forage plants, either the local or Latin name being used, and estimate closely the comparative density of each. Greater accuracy both in listing and in estimating comparative density is secured by running a cord around the corner stakes of the plot and across the plot where the vegetation is dense or forms a rank growth. The value of this work is greatly enhanced by collecting and preparing for the herbarium the main indicator and forage species found on the selected area, and by procuring good photographs showing the character and density of the vegetation additional features of high value may be shown.[1]

The plants here listed as indicators of range conditions are not necessarily the same as those of other regions in the West. As a rule the same genera will be represented, but in many instances the species will be different. As pointed out, reliable indicators of the more serious stages of overgrazing of any region may be determined by study-

[1] In photographing plots it should be the aim to locate, by means of permanently established stakes, the exact place and angle where the original view is procured. Subsequent photographs may then be taken showing the progressive development of the vegetation over the same surface.

ing the plants that characteristically occur on and about bed grounds, on trails, and on other badly depleted areas.

The following list gives the most typical primary and secondary species of the respective covers.

Wheat-grass cover (subclimax type):
- Primary species—
  - Small wheat grass (*Agropyron dasystachyum.*)
  - Blue bunch wheat grass (*Agropyron spicatum*).
  - Slender wheat grass (*Agropyron tenerum*).
- Secondary species—
  - Violet wheat grass (*Agropyron violaceum*).

Porcupine-grass-yellow-brush cover (mixed grass-and-weed type):
- Primary species—
  - Small mountain porcupine grass (*Stipa minor*).
  - Yellow brush (*Chrysothamnus lanceolatus*).
- Secondary species—
  - Blue foxglove (*Pentstemon procerus*).
  - Geum (*Geum oregonense*).
  - June grass (*Koeleria cristata*).
  - Large mountain brome grass (*Bromus marginatus*).
  - Little blue grass (*Poa sandbergii*).
  - Low loco (*Astragalus decumbens*).
  - Nevada blue grass (*Poa nevadensis*).
  - Porter's brome grass (*Bromus porteri*).
  - Single-flowered helianthella (*Helianthella uniflora*).
  - Spiked fescue (*Festuca confinis*).
  - Spiked trisetum (*Trisetum spicatum*).
  - Sweet sage (*Artemisia discolor*).
  - Western fescue (*Festuca occidentalis*).
  - Wild bean (*Lupinus alpestris*).
  - Yarrow (*Achillea lanulosa*).

Foxglove-sweet-sage-yarrow cover (second-weed stage):
- Primary species—
  - Blue foxglove (*Pentstemon procerus*).
  - Sweet sage (*Artemisia discolor*).
  - Yarrow (*Achillea lanulosa*).
- Secondary species—
  - Aster (*Aster frondeus*).
  - Butterweed (*Senecio columbiana*).
  - Cinquefoil (*Potentilla filipes*).
  - Evening primrose (*Lavauxia flava*).
  - False cymopterus (*Pseudocymopterus tidestromii*).
  - False Solomon's seal (*Vagnera stellata*).
  - Geranium (*Geranium viscossissimum*).
  - Horsemint (*Agastache urticifolia*).
  - Large mountain brome grass (*Bromus marginatus*).
  - Low larkspur (*Delphinium menziesii*).
  - Low pea vine (*Lathyrus leucanthus*).
  - Mexican dock (*Rumex mexicanus*).
  - Mountain dandelion (*Crepis acuminata*).
  - Porter's brome grass (*Bromus porteri*).
  - Onion grass (*Melica bulbosa*).

Rubberweed (*Hymenoxys floribunda*).
Sampson's mertensia (*Mertensia sampsonii*).
Scribner's wheat grass (*Agropyron scribneri*).
Snowy onion grass (*Melica spectabilis*).
Sneezeweed (*Helenium hoopesii*).
Tongue-leaved violet (*Viola linguaefolia*).

Ruderal-early-weed cover (first-weed stage):

Primary species—

Douglas knotweed (*Polygonum douglasii*).
Goosefoot or lamb's-quarters (*Chenopodium album*).
Slender-leaved collomia (*Collomia linearis*).
Tarweed (*Madia glomerata*).
Tansy mustard (*Sophia incisa*).
Tolmie's orthocarpus (*Orthocarpus tolmiei*).

Secondary species—

Androsace (*Androsace diffusa*).
Gilia (*Gilia mierantha*).
Knotweed (*Polygonum aviculare*).
Monolepis (*Monolepis nuttalliana*).
Peppergrass (*Lepidium ramossissimum*).

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 792

Contribution from the Bureau of Markets

CHARLES J. BRAND, Chief

Washington, D. C. ✣ July 25, 1919

REPORTS OF STORAGE HOLDINGS OF CERTAIN FOOD PRODUCTS DURING 1918.

Frozen Meats, Cured Meats and Lard, Frozen Fish, Cured Herring and Mild Cured Salmon.

By John O. Bell, *Assistant in Market Surveys.*

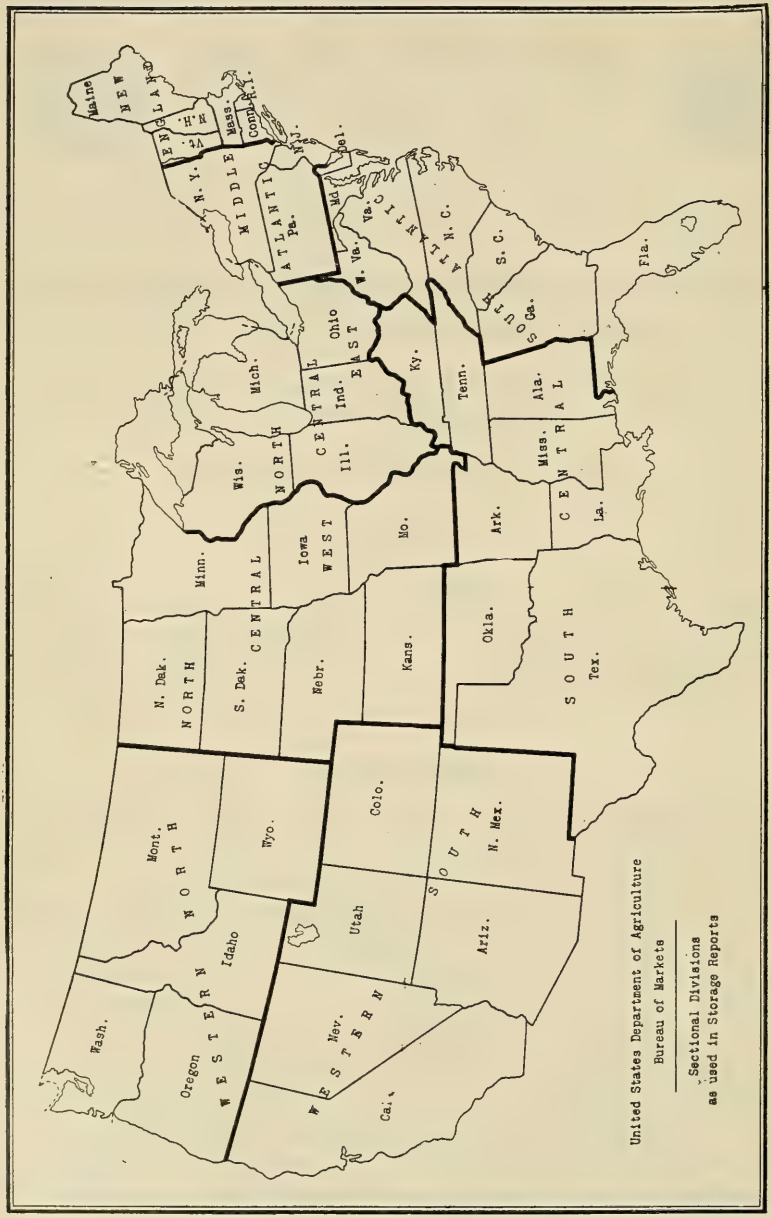
CONTENTS.

INTRODUCTION.

This bulletin is the third of a series reviewing the work of the Bureau of Markets, U. S. Department of Agriculture, in compiling reports of storage holdings of certain food products.

The first of the series was U. S. Department of Agriculture Bulletin 709, entitled "Reports of Storage Holdings of Certain Food Products." It described the storage work of the Bureau of Markets and the methods of securing the information and of compiling the reports. It summarized the work accomplished up to January 1, 1918, and reviewed the cold storage season of 1916 and 1917 for apples, butter, American cheese, and case eggs. It also reviewed the reports received during 1917 on the storage holdings of frozen and cured meats.

The second of the series was U. S. Department of Agriculture Bulletin 776, entitled "Cold Storage Reports, Season 1917-1918." It reviewed the reports of that season on apples, creamery and packing stock butter, American cheese, case and frozen eggs, and frozen poultry.


Maine
NEW ENGLAND
Vt.
N. H.
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W. Va.
ATLANTIC
N. C.
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SOUTH
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EAST CENTRAL
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Ala.
Mich.
Ill.
Miss.
Wis.
NORTH CENTRAL
Iowa
WEST CENTRAL
Mo.
Ark.
La.
Minn.
N. Dak.
NORTH
S. Dak.
Nebr.
Kans.
Okla.
SOUTH
Tex.
Mont.
NORTH
Wyo.
Colo.
SOUTH
N. Mex.
Idaho
Utah
Ariz.
Wash.
Oregon
WESTERN
Nev.
WESTERN
Cal.
United States Department of Agriculture
Bureau of Markets
Sectional Divisions
as used in Storage Reports

FIG. 1.

The present bulletin reviews the reports received during 1918 on the storage holdings of frozen and cured meats, lard, frozen fish, cured herring, and mild cured salmon. A series of tables shows the frozen and cured meat holdings at the peak load of the season for that commodity, segregated by sections. These tables include the number of storages reporting for a certain date in each geographical section, and the holdings of these firms. They also furnish comparisons between the stocks reported on these dates with the stocks reported for the same dates of the previous year. The comparison is based on the storages reporting for both dates.

For each variety of meat products and fish, another table shows the holdings of each month on the date of reporting and the relation, expressed in percentage, of the holdings of each month to the peak load of the season and the increase or decrease during each month, both in actual number of pounds and in percentage. The holdings in these tables are based on the actual number of pounds reported, plus an estimate of the stocks of the storages that failed to report. The estimates of the stocks of the unreported firms are based on their holdings reported for the preceding month. It is assumed that the percentage of increase or decrease in their stocks was the same as the percentage of increase or decrease in the stocks of the storages that reported. The unreported stocks in any month never amount to more than 1 per cent of the total holdings.

Another series of tables shows the quantities reported and the comparison of the holdings of each month with those of the same date in the preceding year. This comparison also is based, in each case, on the storages reporting for both dates.

Two series of charts are included in this bulletin. One series shows graphically the comparative monthly holdings during 1918, based on the tables of monthly holdings, including estimates. The other series covers meats only, showing graphically the relative monthly holdings for the years 1916 to 1918, inclusive.

Each chart in this latter series shows the relation, expressed in percentage, of each month's holdings of the particular commodity to the peak load holdings of the entire three years. They are based on the monthly increases and decreases as compiled in the regular monthly reports of the Bureau of Markets. In making such comparisons the reports of those firms having no holdings on one of the dates compared are included. If a firm begins business or ceases business in the intervening period, it is included in the comparison as having no holdings on the date on which it is not in business.

REVIEW OF THE 1918 COLD STORAGE HOLDINGS OF FROZEN MEATS.

The Bureau of Markets collects and publishes information regarding the monthly cold storage holdings of three classes of frozen meats—frozen beef, frozen pork, and frozen lamb and mutton. As reports are received from practically all cold storage and packing plants in the United States, the information secured shows the quantities on hand on the first of each month in both public and private cold storage warehouses and in packing house plants.

The maximum quantities reported for each of these commodities on the first of any one month during the year were as follows: Frozen beef on January 1, 1918, 309,621,874 pounds; frozen pork on May 1, 1918, 134,633,021 pounds; frozen lamb and mutton on December 1, 1918, 9,046,250 pounds.

These figures, of course, do not represent the total quantities frozen during the year, for, as no information has been secured regarding monthly receipts and deliveries, it is obvious that some meats may have been frozen and removed from the warehouses during the month, which would not appear in the reports of the stocks on hand on the first day of the month. The quantities reported since August 1, 1918, are stocks of carcasses and cuts only and do not include trimmings and offal. Previous to that date, through a misunderstanding, a few warehouses reported trimmings and edible offal with their other meat stocks. From corrected reports received for several months, it is estimated that the trimmings and offal thus included amount to approximately 3 per cent of the total stocks reported.

FROZEN BEEF.

The reports of the Bureau of Markets have shown extraordinarily large quantities of frozen beef stocks in cold storage during the year. To a great extent this is accounted for by the large quantities frozen for shipment overseas. It is probable that much more was frozen and shipped between reports and therefore is not shown in the monthly reports.

The reports showed that the largest stocks held at any one time during the year were in storage on January 1, 1918. Table 1 shows the holdings of that date segregated by geographical sections and a comparison of the stocks of January 1, 1918, with those of January 1, 1917. This comparison is based on those storages that reported their holdings for both dates.

TABLE 1.—*Cold storage holdings of frozen beef as reported on January 1, 1918.*

Section.	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	33	18,123,176	5.8	27	4,317,922	6,907,222	+ 60.0
Middle Atlantic	83	46,104,962	14.9	72	50,504,794	43,501,498	− 13.9
South Atlantic	27	1,798,926	.6	25	1,580,006	1,793,826	+ 13.5
N. Central (east)	74	154,173,798	49.8	55	98,439,463	138,051,374	+ 40.2
N. Central (west)	60	72,033,748	23.3	49	37,070,067	56,210,673	+ 51.6
South Central	30	6,716,079	2.2	19	5,398,610	6,091,953	+ 12.8
Western (north)	28	4,964,026	1.6	21	2,796,608	4,000,474	+ 43.0
Western (south)	33	5,707,159	1.8	29	2,334,340	5,595,123	+139.7
Total	369	309,621,874	100.0	297	202,441,810	262,152,143	+ 29.5

Table 1 shows that almost one-half of the frozen beef held at that time was stored in the North Central States east of the Mississippi River, nearly one-fourth in the North Central States west of the Mississippi and only 15 per cent in the Middle Atlantic States. Most of the holdings in the North Central East section were stored in Chicago, that city having 43 per cent of the total stocks of the country. Greater New York stored the second largest amount, or 7.9 per cent, St. Louis, third, or 5.3 per cent, and Boston fourth, or 4.2 per cent.

The percentage stored in the North Central East section increased during January and February, 1918, from 49.8 per cent on January 1 to 52 per cent on March 1, then decreased until July 1, when only 37.9 per cent was stored in that section. By December 1 the percentage had again increased to 44.2 per cent.

The percentage in the North Central West section increased to 23 per cent on February 1, then decreased monthly until September 1, when only 11.6 per cent was stored in that section; it then increased to 15 per cent on December 1.

The percentage stored in New York, New Jersey, and Pennsylvania decreased to 13.4 per cent in February, then increased monthly until September 1, when 34.4 per cent was held in these States. The percentage again decreased, and on December 1 they held 24.2 per cent of the total holdings.

Table 2 gives the monthly holdings reported, plus the estimated holdings of those storages whose reports were not received. It also shows the increase and decrease in holdings monthly. Comparing this table with Table 1, it is shown that the quantities unreported monthly were very small, never amounting to more than 2 per cent.

TABLE 2.—*Monthly cold storage holdings of frozen beef during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	315,571,879	100.0	−23,457,530	− 7.4
February	292,114,349	92.6	−16,000,304	− 5.5
March	276,114,045	87.5	+ 7,673,927	+ 2.8
April	283,787,972	89.9	−56,212,451	−19.8
May	227,575,521	72.1	−23,459,245	−10.3
June	204,116,276	64.7	−34,288,658	−16.8
July	169,827,618	53.8	+26,692,705	+15.7
August	196,520,323	62.3	−11,331,375	− 5.8
September	185,188,948	58.7	+ 9,294,075	+ 5.0
October	194,483,023	61.6	+29,390,135	+15.1
November	223,873,158	70.9	+ 5,837,481	+ 1.9
December	229,710,639	72.8	+67,148,421	+29.5

By the curves indicating the increases and decreases in holdings during the months involved, figure 2 shows graphically the relative monthly holdings for the years 1916 to 1918, inclusive.

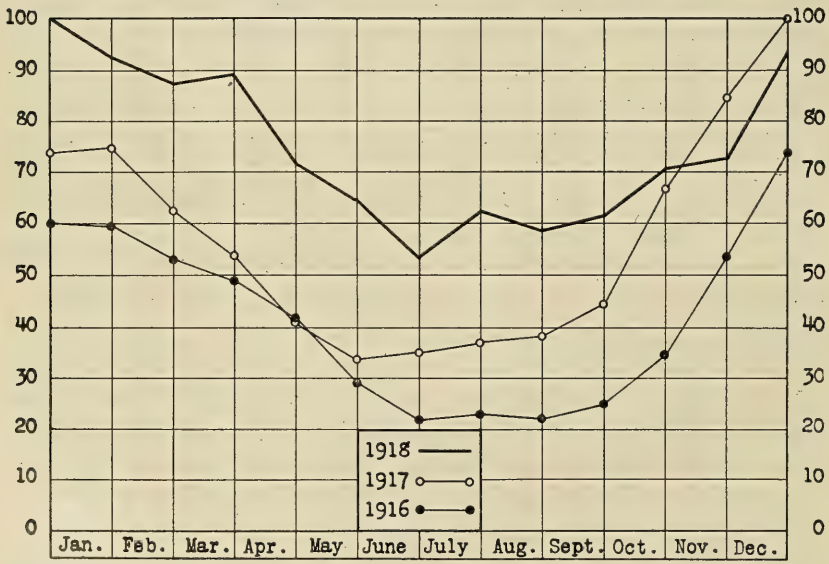

FIG. 2.—Relative monthly cold storage holdings of frozen beef during 1916, 1917, and 1918. Base 100 equals holdings on January 1, 1918.

For several months during the year a few firms failed to report their holdings. A careful estimate has been made of their holdings for these dates. The estimate for each month was based on the holdings reported for the previous and succeeding months.

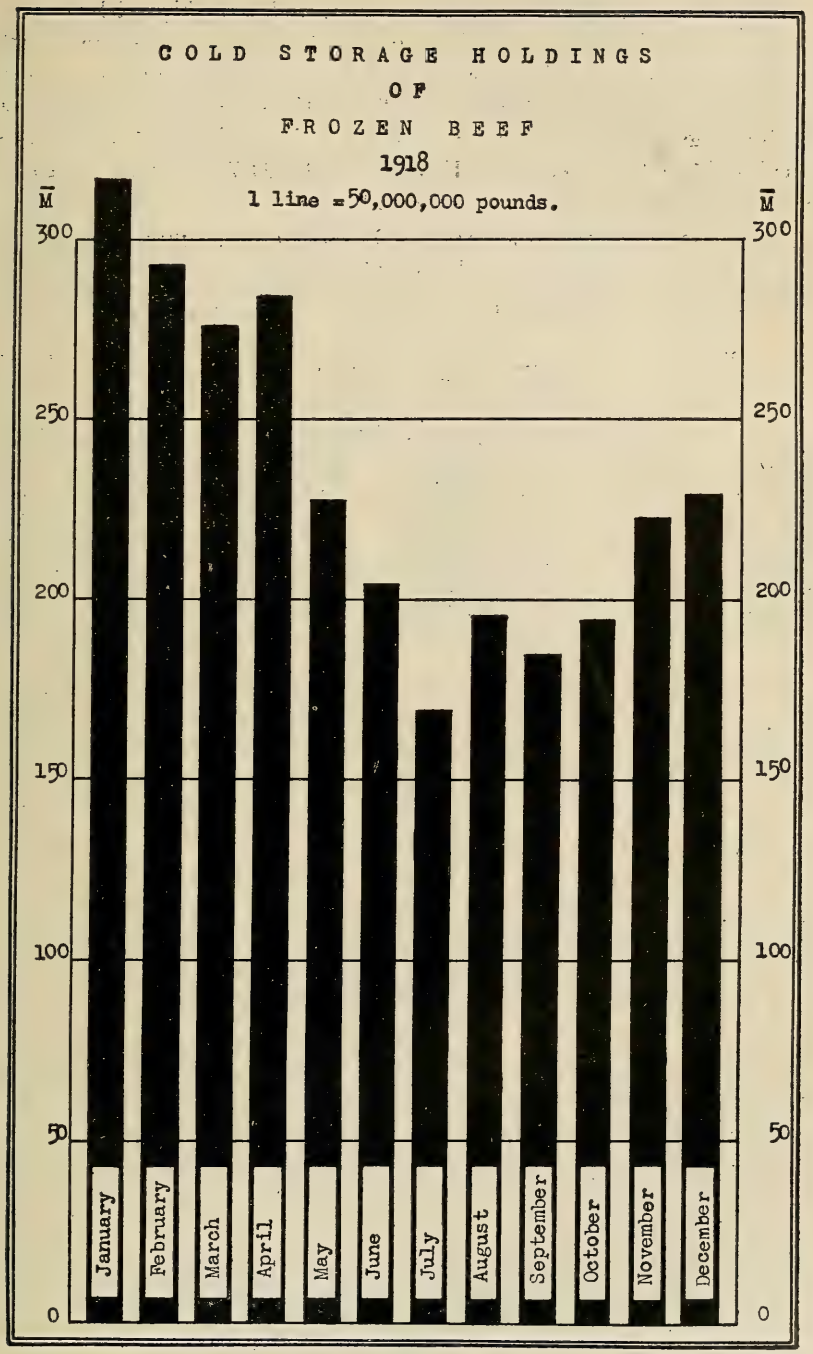
COLD STORAGE HOLDINGS
OF
FROZEN BEEF
1918
1 line = 50,000,000 pounds.
M
300
250
200
150
100
50
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 3.

Table 3 shows the total quantity reported monthly with a comparison of the holdings of each month with those of the same month in 1917. This comparison also is based on the stocks of those warehouses reporting for both dates. All months except December show the holdings of 1918 to be much more than those of 1917, the increases varying from 8 per cent on February 1 to 91.7 per cent or about ninety-five million pounds on June 1.

TABLE 3.—*Monthly cold storage holdings of frozen beef during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	369	309,621,874	297	202,441,810	262,152,143	+29.5
February	379	292,044,788	308	190,908,760	206,244,760	+ 8.0
March	386	276,114,045	318	169,792,699	188,087,763	+10.8
April	380	283,787,972	322	154,192,972	250,868,255	+62.7
May	383	227,575,521	326	118,391,253	206,400,834	+74.3
June	369	204,116,276	321	103,006,888	197,465,175	+91.7
July	377	169,827,618	328	109,353,514	163,219,536	+49.3
August	360	196,520,323	323	108,728,886	182,486,446	+67.8
September	368	185,188,948	327	100,453,086	170,241,546	+69.5
October	370	194,483,023	327	119,221,128	170,121,857	+42.7
November	371	222,267,572	339	179,031,590	195,800,989	+ 9.4
December	380	229,607,772	347	235,664,360	203,217,071	−13.8

Figure 3 is a chart showing the comparative monthly holdings of frozen beef for 1918. The quantities indicated on the chart are based on the quantities reported plus the estimated holdings of unreported warehouses as given in Table 3. The monthly increases and decreases as shown in Table 3 and on this chart do not have any great degree of regularity. They show a general decrease to July 1, except for a slight increase during March. From July 1 until the end of December, the holdings increased monthly except for a slight decrease during the month of August. The greatest decrease, amounting to more than 56,000,000 pounds, occurred during April. In December the holdings were increased by more than 67,000,000 pounds.

FROZEN PORK.

During the months of April to July, 1918, inclusive, the holdings of frozen pork were much larger than for the previous two years. From August 1 to January 1 the holdings for the three years have shown little variation. Table 4 shows the holdings that were reported on May 1, 1918, segregated by sections. The holdings of that month are the maximum of the season and the largest quantity that has been reported to the Bureau of Markets since these reports have been collected. The table also compares the holdings of May 1, 1918, with those of May 1, 1917, the comparison being based on the holdings of only those warehouses which reported for both dates.

TABLE 4.—*Cold storage holdings of frozen pork as reported on May 1, 1918.*

Section.	Reported for May 1, 1918.			Comparison with May 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	May 1, 1917.	May 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	35	10,478,041	7.8	31	7,226,239	10,031,810	+ 38.8
Middle Atlantic	83	22,323,967	16.6	75	9,095,533	22,176,752	+143.8
South Atlantic	25	1,869,225	1.4	24	477,167	1,793,047	+275.8
N. Central (east)	76	47,755,942	35.4	65	21,226,318	42,616,383	+100.8
N. Central (west)	60	38,846,295	28.8	56	27,373,956	37,577,821	+ 37.3
South Central	31	3,467,867	2.6	25	3,325,443	2,866,967	− 13.8
Western (north)	22	3,845,590	2.9	18	2,741,160	3,820,216	+ 39.4
Western (south)	28	6,046,094	4.5	24	3,262,004	5,783,548	+ 77.3
Total	360	134,633,021	100.0	318	74,727,820	126,666,544	+ 69.5

More than 80 per cent of the stocks of May 1 were stored in the Middle Atlantic and North Central sections. Chicago cold storages held one-fourth of the stocks and Greater New York cold storages 13.6 per cent. The percentages in the North Central and Middle Atlantic sections varied from 80.8 per cent to 71.5 per cent in October.

Table 5 shows the holdings of each month during the year, including both the stocks reported and an estimate of the holdings of those firms whose reports were not received. It also shows the amount of monthly increases and decreases.

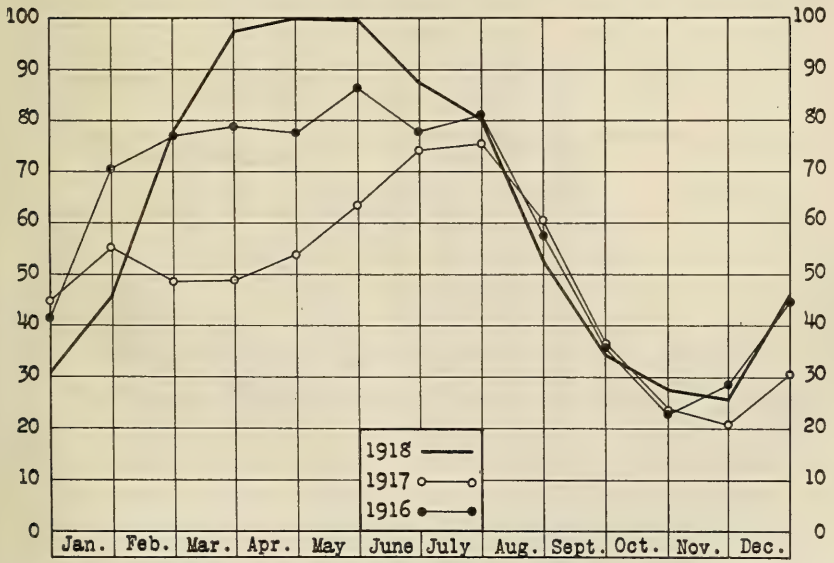

FIG. 4.—Relative monthly cold storage holdings of frozen pork during 1916, 1917, and 1918. Base 100 equals holdings on May 1, 1918.

TABLE 5.—*Monthly cold storage holdings of frozen pork during 1918, and increase or decrease during each month.*

Month.	Holdings on first of each month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	41,663,343	30.9	+19,995,681	+48.0
February	61,659,024	45.8	+42,971,028	+69.7
March	104,630,052	77.7	+26,700,426	+25.5
April	131,330,478	97.5	+ 3,302,543	+ 2.5
May	134,633,021	100.0	− 501,507	− 0.4
June	134,131,514	99.6	−16,155,762	−12.0
July	117,975,752	87.6	− 9,755,280	− 8.3
August	108,220,472	80.4	−36,835,602	−34.0
September	71,384,870	53.0	−24,792,232	−34.7
October	46,592,638	34.6	− 9,624,602	−20.7
November	36,968,036	27.5	− 2,218,446	− 5.9
December	34,749,590	25.9	+26,510,445	+80.7

Table 6 shows the total holdings reported for each month during the year together with the comparison of the holdings of each month with those of the same date of the previous year. It will be observed that in April, May, and June the holdings of 1918 were approximately 50,000,000 pounds greater than those of 1917. However, the 1917 stocks for those months were much smaller than those of 1916. In figure 4 are plotted the relative holdings of each month, for the years 1916 to 1918, inclusive, on a percentage basis. This shows not only the monthly stocks during the three years but also the monthly increase and decrease in holdings.

TABLE 6.—*Monthly cold storage holdings of frozen pork during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	327	41,100,684	235	50,563,951	33,167,655	−34.4
February	349	61,646,499	271	66,061,889	55,155,327	−16.5
March	364	104,630,052	294	63,352,144	89,288,856	+40.9
April	362	131,330,478	305	64,996,160	112,676,886	+73.4
May	360	134,633,021	318	74,727,820	126,666,544	+69.5
June	359	134,131,514	310	77,533,678	127,880,376	+64.9
July	355	117,975,752	320	91,562,278	112,045,038	+22.4
August	353	108,220,472	313	96,648,335	102,889,405	+ 6.5
September	345	71,384,870	318	72,286,006	69,960,132	− 3.2
October	359	46,592,638	320	39,767,455	44,880,387	+12.9
November	350	37,505,113	311	25,347,070	35,485,652	+40.0
December	351	34,621,846	323	23,504,075	33,842,445	+44.0

Figure 5 shows graphically the quantities of frozen pork in cold storage on the first day of each month during the year 1918. It is based on the quantities given in Table 5. The largest increase in holdings occurred during the month of February when the increase

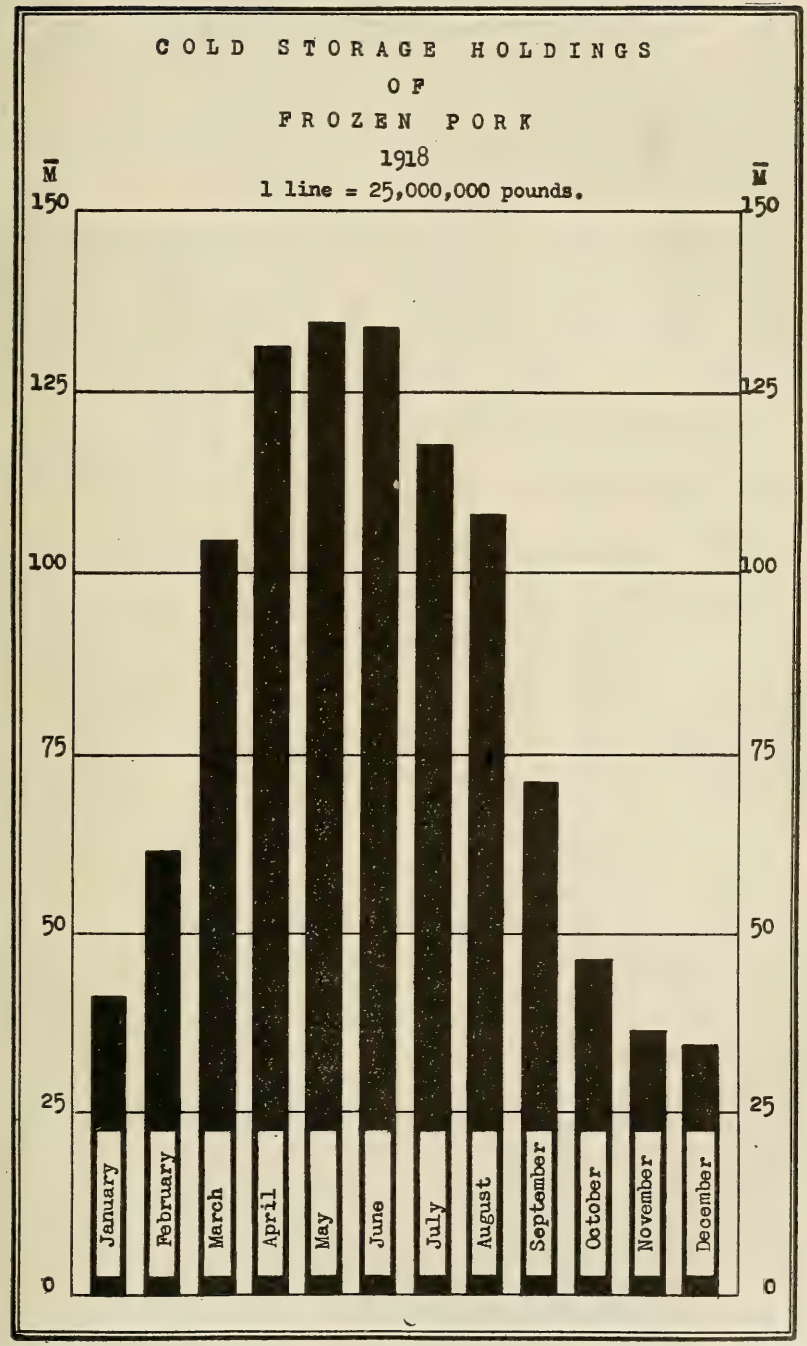
COLD STORAGE HOLDINGS
OF
FROZEN PORK
1918
1 line = 25,000,000 pounds.
M
150
125
100
75
50
25
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 5.

was nearly 43,000,000 pounds. The decreases were more regular, and varied from 500,000,000 pounds during May to 36,800,000 pounds during August. The stocks increased monthly until May 1, then decreased until December 1. During December there was an increase of 26½ million pounds, indicating that the 1919 stocks were beginning to go into cold storage.

FROZEN LAMB AND MUTTON.

The holdings of frozen lamb and mutton as reported on December 1, 1918, amounted to 9,046,250 pounds. All cold storages and packing plants on the list of the Bureau of Markets reported their holdings for that date. These stocks were 53.7 per cent greater than on December 1, 1917. Table 7 segregates the holdings of December 1, 1918, by geographical sections, and compares the holdings of each section with those of December 1, 1917.

TABLE 7.—*Cold storage holdings of frozen lamb and mutton as reported on December 1, 1918.*

Section.	Reported for December 1, 1918.			Comparison with December 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	December 1, 1917.	December 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	23	965,934	10.7	22	938,378	965,891	+ 2.9
Middle Atlantic	57	2,944,048	32.5	53	2,209,845	2,738,978	+ 23.9
South Atlantic	14	164,539	1.8	12	108,369	163,889	+ 51.2
N. Central (east)	34	2,351,142	26.0	29	1,118,979	2,031,756	+ 81.6
N. Central (west)	35	1,608,718	17.8	31	428,480	1,411,830	+229.5
South Central	16	326,575	3.6	13	61,405	324,507	+428.5
Western (north)	27	204,473	2.3	23	306,338	198,103	− 35.3
Western (south)	21	480,821	5.3	20	233,976	476,383	+103.6
Total	227	9,046,250	100.0	203	5,405,770	8,311,337	+ 53.7

It will be observed that of the 9,046,250 pounds reported for December 1, 32.5 per cent was stored in the Middle Atlantic States, 26 per cent in the North Central East section, 17.8 per cent in the Central West section, and 10.7 per cent in the New England section, a total of 87 per cent of the total United States holdings. Approximately 28 per cent was stored in greater New York and 25 per cent in Chicago.

Table 8 shows the total holdings for each month during 1918, these totals being based on the stocks of the warehouses reporting, plus an estimate of the holdings of storages not reporting. By comparing this table with Table 8 it will be observed that the unreported stocks amounted to a very small percentage of the quantities reported monthly. Using the stocks of December 1 as a base, this table also shows the percentage of the holdings of each month, the monthly increase and decrease in holdings expressed in pounds, and the percentage that this decrease is of the stocks of the previous month.

TABLE 8.—*Monthly cold storage holdings of frozen lamb and mutton during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	7,403,093	81.9	−1,088,073	−14.7
February	6,315,020	69.8	+1,540,161	+24.4
March	7,855,181	86.9	−1,507,021	−19.2
April	6,348,160	70.2	−2,315,273	−36.5
May	4,032,887	44.6	+ 209,873	+ 5.2
June	4,242,760	46.9	− 749,299	−17.7
July	3,493,461	38.6	+ 676,079	+19.4
August	4,169,540	46.1	− 123,163	− 3.0
September	4,046,377	44.8	+1,195,384	+29.5
October	5,241,761	58.0	+3,042,570	+58.0
November	8,284,331	91.6	+ 761,919	+ 9.2
December	9,046,250	100.0	+3,398,668	+37.6

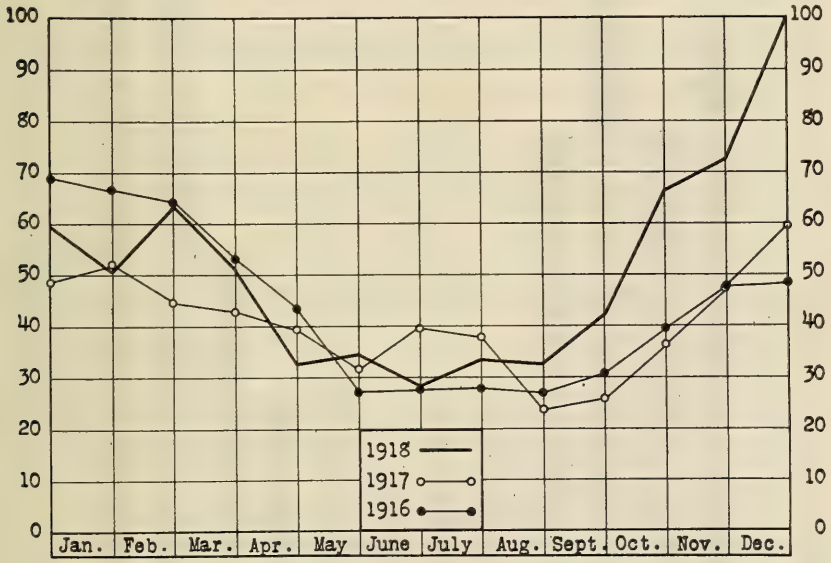

FIG. 6.—Relative monthly cold storage holdings of frozen lamb and mutton during 1916, 1917, and 1918. Base 100 equals holdings on January 1, 1919.

Table 9 shows the holdings reported monthly during the year and a comparison of the holdings of each month with those of the same date of the previous year. This comparison includes only the holdings of those warehouses reporting for both dates. Figure 6 shows the relative holdings of each month for the past three years. This chart is prepared on a percentage basis and it also shows the relative monthly percentage of increase or decrease during those years. It shows that the movement of frozen lamb and mutton to and from storage was rather erratic.

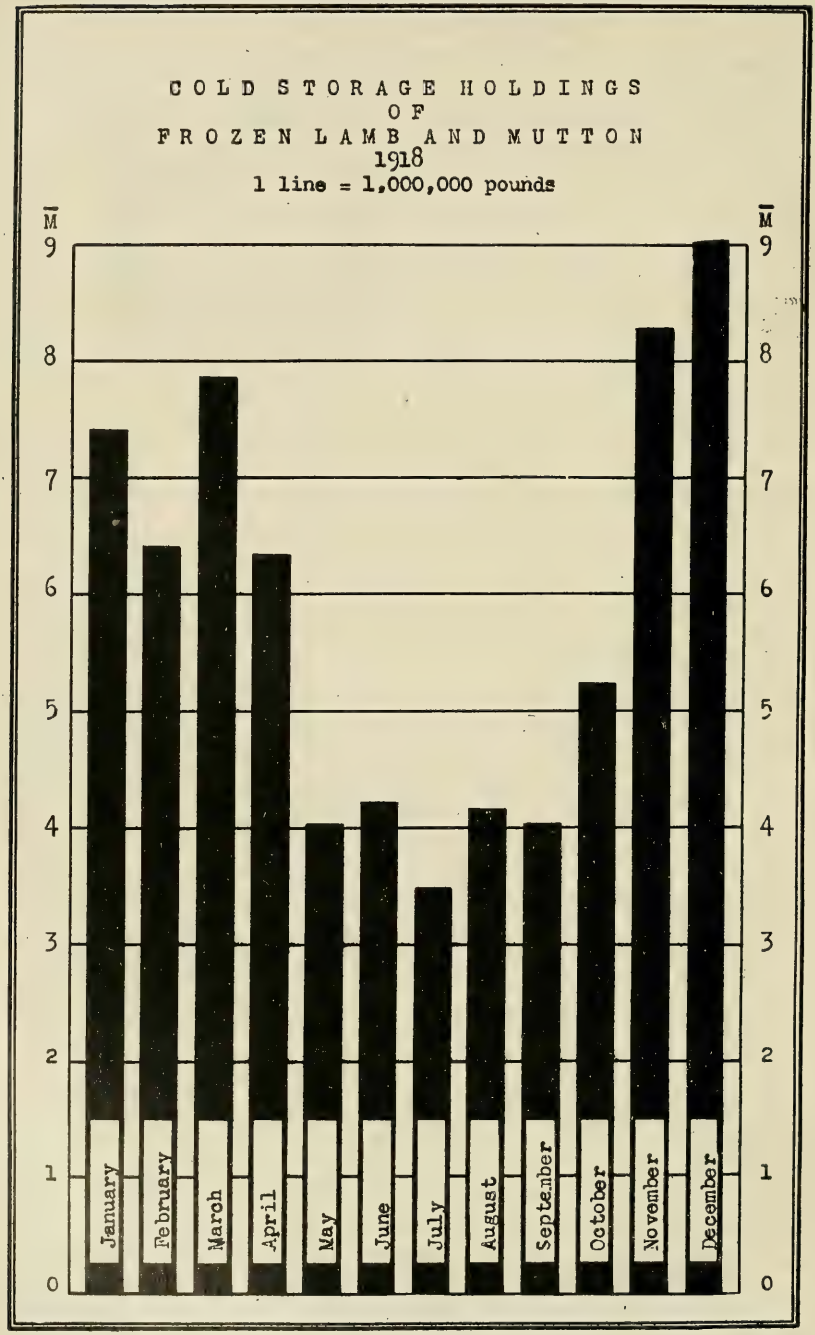
COLD STORAGE HOLDINGS
OF
FROZEN LAMB AND MUTTON
1918
1 line = 1,000,000 pounds
M
9
8
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 7.

TABLE 9.—*Monthly cold storage holdings of frozen lamb and mutton during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	200	7,356,166	147	4,885,678	5,456,148	+11.7
February	201	6,314,420	157	5,895,319	5,365,317	− 9.0
March	210	7,855,181	166	4,948,954	6,929,546	+40.0
April	211	6,348,160	170	4,871,723	5,653,730	+16.1
May	209	4,032,887	171	4,368,770	3,663,231	−16.1
June	201	4,242,760	169	3,508,294	3,963,836	+13.0
July	205	3,493,461	173	4,380,373	3,149,321	−28.1
August	214	4,101,370	179	3,912,194	3,728,697	− 4.7
September	210	4,046,377	178	2,715,659	3,788,231	+39.5
October	225	5,241,761	185	2,768,033	4,543,219	+64.1
November	231	8,610,224	195	4,193,668	7,738,444	+84.5
December	226	9,046,250	203	5,405,770	8,311,337	+53.7

Figure 7 illustrates the relative quantities held on the first day of each month during 1918.

REVIEW OF THE 1918 STORAGE HOLDINGS OF CURED MEATS AND LARD.

The three varieties of cured meats on which reports are made by the Bureau of Markets are cured beef, dry salt pork, and pickled pork. The reports also cover the stocks of lard and miscellaneous meats. Included in miscellaneous meats are all stocks of beef, pork and mutton trimmings and all stocks of beef, pork and mutton edible offal whether frozen, cured or otherwise prepared for food. It does not include sausage and canned meat products. Reports on these commodities were not requested until August 1, 1918, and sufficient data have not been secured to show the holdings and movement for a season. In the cured meat products are included meats in process of cure as well as meat on which the process of curing is completed.

CURED BEEF.

The largest quantity of cured beef reported during the season was held on January 1, 1918. The 363 storages that reported for that date showed stocks of 38,279,264 pounds. It is estimated that the holdings of the 3 storages that did not report amounted to 963,307 pounds, making a total of 39,242,571 pounds. This was about 3⅓ per cent less than the holdings for January 1, 1917.

TABLE 10.—*Cold storage holdings of cured beef as reported on January 1, 1918.*

Section.	Reported for January 1, 1918.			Comparison with January 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	January 1, 1917.	January 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	26	1,389,312	3.6	20	821,371	1,199,312	+ 46.0
Middle Atlantic	95	4,553,085	11.9	80	5,649,827	4,164,069	− 26.3
South Atlantic	34	648,422	1.7	29	324,424	623,144	+ 92.1
N. Central (east)	94	16,558,496	43.3	87	17,032,000	16,338,459	− 4.1
N. Central (west)	49	13,294,063	34.7	47	12,985,971	12,913,430	− 0.6
South Central	22	607,197	1.6	16	427,529	572,821	+ 34.0
Western (north)	20	374,198	1.0	19	488,398	326,313	− 33.2
Western (south)	23	854,491	2.2	18	509,720	838,298	+ 64.5
Total	363	38,279,264	100.0	316	38,239,240	36,975,846	− 3.3

Table 10 shows the holdings as reported on January 1, 1918, segregated by geographical sections and a comparison of the holdings of that date with those of January 1, 1917. This segregation shows that 90 per cent of the total holdings were stored in the Middle Atlantic and North Central sections. More than 900,000 pounds of the unreported stocks were stored in Chicago, so the North Central East section held 44.5 per cent of the total holdings of the United States, while Chicago storages alone held 38.2 per cent. Greater New York held a little less than 5 per cent of the total stocks.

TABLE 11.—*Monthly storage holdings of cured beef during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	39,242,571	100.0	− 449,932	− 1.1
February	38,792,639	98.9	−1,218,058	− 3.1
March	37,574,581	95.7	−2,173,443	− 5.8
April	35,401,132	90.2	−5,140,153	−14.5
May	30,260,979	77.1	−3,920,511	−13.0
June	26,340,468	67.1	−2,704,960	−10.3
July	23,635,508	60.2	+6,000,604	+25.4
August	29,636,112	75.5	+ 575,405	+ 1.9
September	30,211,517	77.0	−1,282,457	− 4.2
October	28,929,060	73.7	+1,225,298	+ 4.2
November	30,154,358	76.8	+2,428,809	+ 8.0
December	32,583,167	83.0	+3,583,175	+11.0

Table 11 shows the total holdings of each month during the year and the percentage of the holdings of each month based on the stocks of January 1. It also shows the monthly increase and decrease in holdings and the percentage that each month's increase or decrease is of the stocks on hand on the first day of that month. The data in this table are based on the total monthly stocks reported, plus an estimate of the unreported holdings.

TABLE 12.—*Monthly cold storage holdings of cured beef during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	363	38,279,264	290	37,301,283	35,762,222	− 4.1
February	370	38,792,639	307	35,890,829	35,950,372	+ 0.2
March	375	37,608,731	320	37,660,065	36,508,067	− 3.1
April	383	35,401,132	330	30,601,470	32,954,304	+ 7.7
May	383	31,236,415	333	29,408,560	29,409,829	+ 0.004
June	380	26,340,468	342	30,831,335	24,259,459	−21.3
July	373	23,635,508	330	35,679,158	23,151,585	−35.1
August	371	29,636,112	330	32,401,017	28,773,872	−11.2
September	373	30,211,517	340	30,289,505	29,037,934	− 4.1
October	381	28,929,060	348	31,246,459	27,968,521	−10.5
November	382	29,514,914	349	32,222,692	28,489,443	−11.6
December	363	32,583,167	346	38,324,795	31,894,094	−16.8

Table 12 shows the quantities reported for the first day of each month during the year together with a comparison of the holdings for the same dates for 1917. The stocks were less for all months, except February, April, and May. April stocks showed an increase of 7.7 per cent, while February and May stocks showed less than 1 per cent increase.

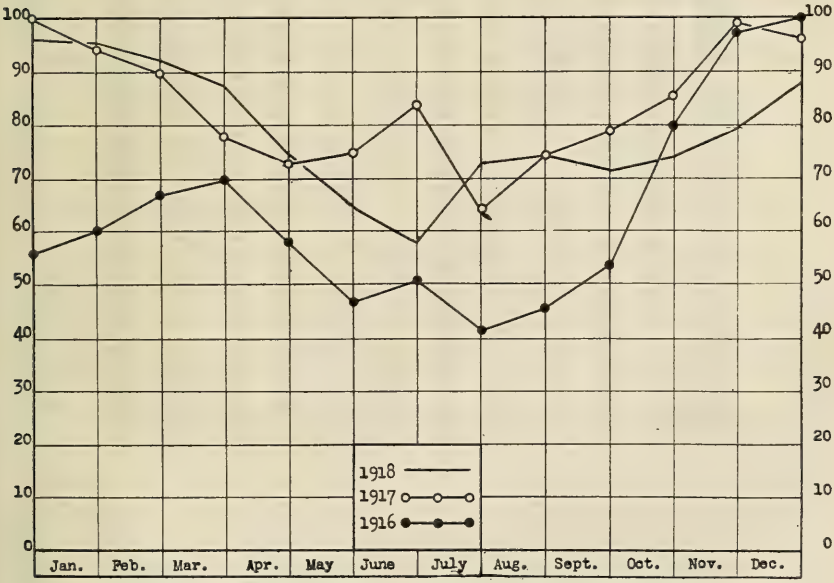

FIG. 8.—Relative monthly storage holdings of cured beef during 1916, 1917, and 1918. Base 100 equals holdings on January 1, 1917.

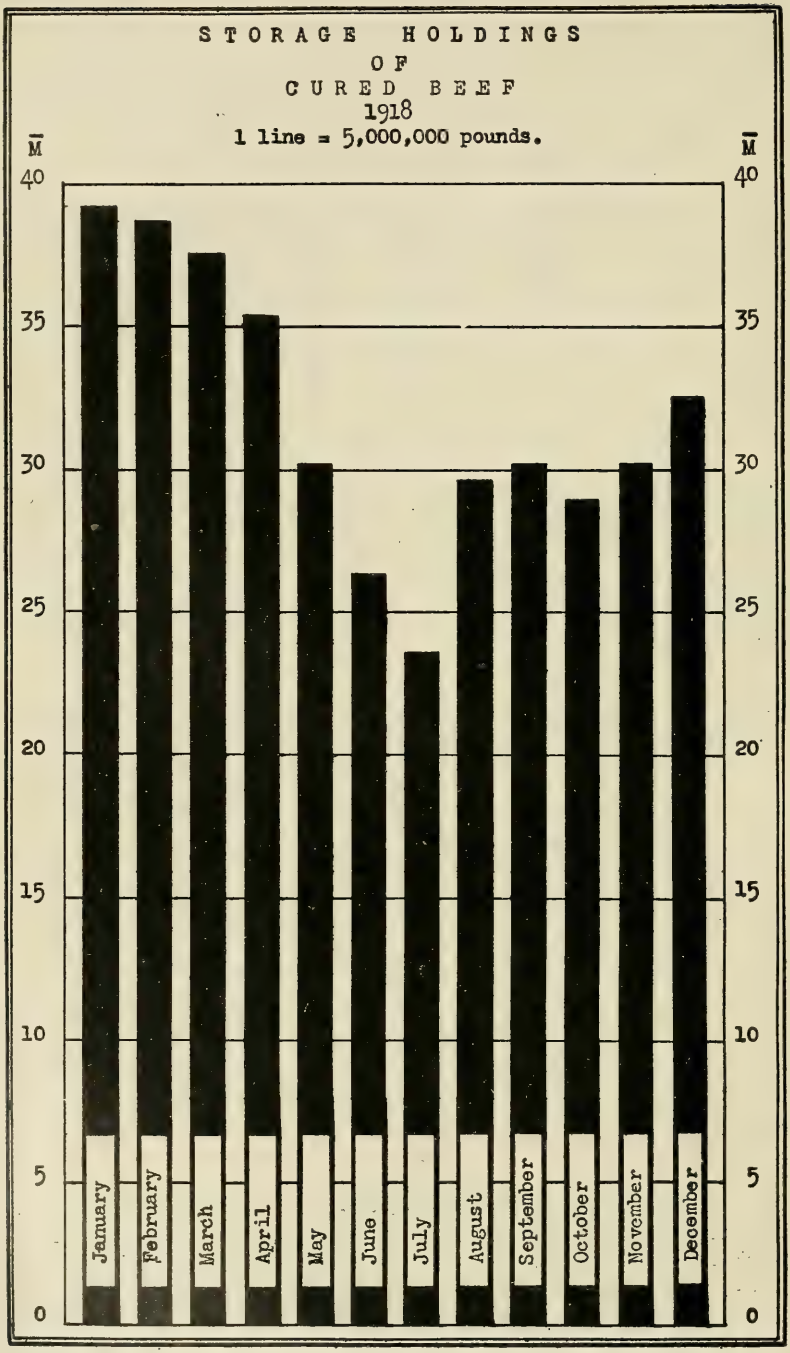
STORAGE HOLDINGS
OF
CURED BEEF
1918
1 line = 5,000,000 pounds.
M
40
35
30
25
20
15
10
5
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 9.

Figure 8 shows the relative monthly holdings for the years 1916 to 1918, inclusive. It is prepared on a percentage basis and also shows the relative monthly movement. It will be observed that the stocks of 1916, except for the months of November and December, were considerably smaller than those of the two preceding years.

Figure 9 illustrates the relative quantities on hand on the first day of each month during 1918. The holdings decreased monthly from January to June, then increased monthly until December, excepting for a slight decrease during September. The holdings never reached a very low point. The stocks on July 1 amounted to 23,635,508 pounds, a decrease of only 42.6 per cent from the maximum holdings of January 1.

DRY SALT PORK.

The reports received by the Bureau of Markets during 1918 showed extremely large holdings of dry salt pork. The largest quantity reported was held on June 1, when 480 cold storages and packing houses reported stocks of 490,193,305 pounds. Reports were not received from two warehouses for that date. Basing an estimate on their reports for other months, it is probable that their holdings on that date amounted to approximately 18,000 pounds. The reports of the 436 storages that reported for both June 1, 1917, and June 1, 1918, showed that the amount held on June 1 was 125 per cent more than was stored on the same date of the previous year.

TABLE 13.—*Cold storage holdings of dry salt pork as reported on June 1, 1918.*

Section.	Reported for June 1, 1918.			Comparison with June 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	June 1, 1917.	June 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	23	19,608,411	4.0	21	10,138,692	18,570,112	+ 83.2
Middle Atlantic	81	22,474,766	4.5	74	8,419,180	22,346,140	+165.4
South Atlantic	64	7,193,021	1.5	55	4,802,019	6,246,308	+ 30.1
N. Central (east)	122	208,262,182	42.5	116	88,303,950	207,278,712	+134.7
N. Central (west)	79	204,478,633	41.7	74	87,545,140	199,959,376	+128.4
South Central	46	19,545,621	4.0	40	10,734,072	18,718,829	+ 74.4
Western (north)	31	3,347,439	.7	29	1,334,493	3,248,006	+143.4
Western (south)	34	5,283,232	1.1	27	2,524,153	4,671,727	+ 85.1
Total	480	490,193,305	100.0	436	213,801,699	481,039,210	+125.0

More than 84 per cent of the stocks of June 1, 1918, were stored in the North Central States, 42.5 per cent being east of the Mississippi River and 41.7 per cent west of the Mississippi. More than 70 per cent of the holdings of each month throughout the year were held in the North Central States. One-fourth of the total holdings of the United States on June 1, 1918, was stored in Chicago.

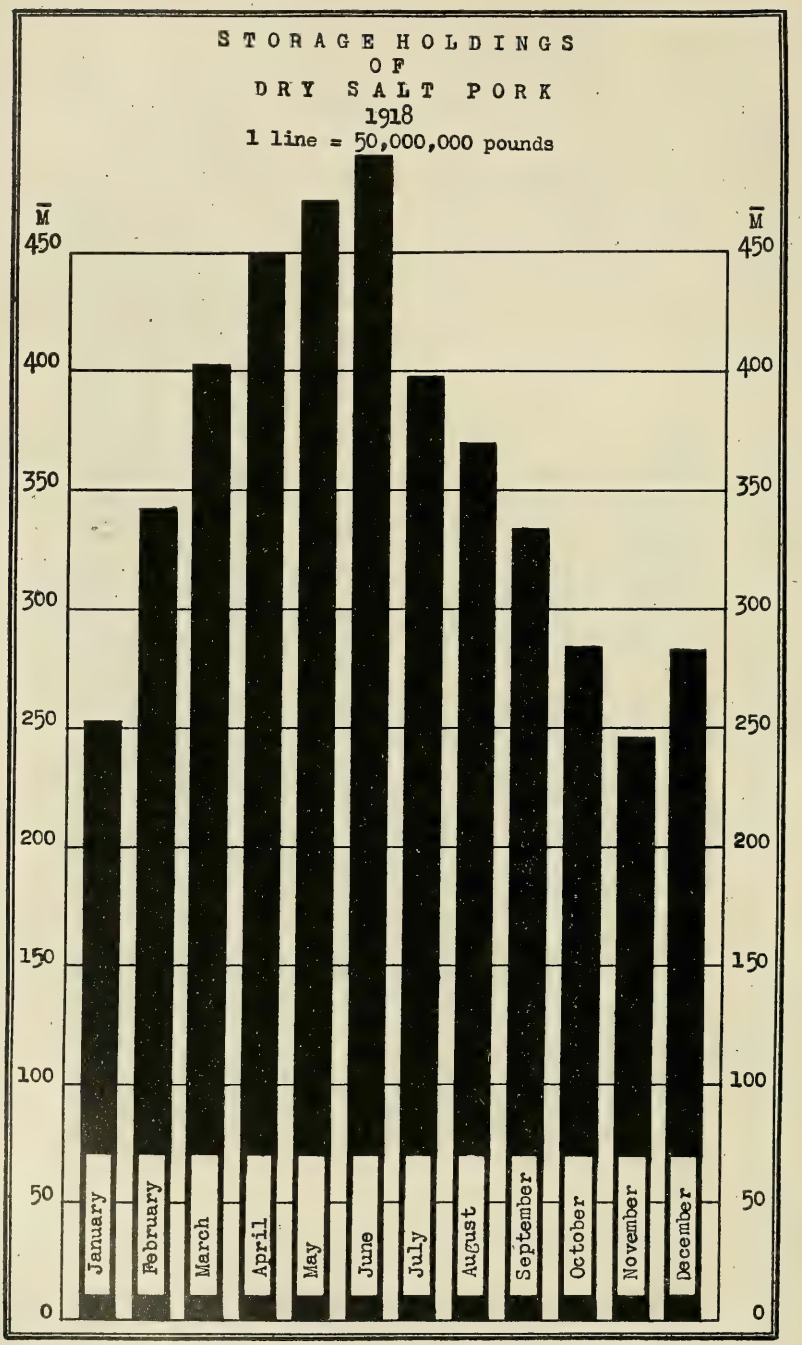
STORAGE HOLDINGS
OF
DRY SALT PORK
1918
1 line = 50,000,000 pounds
M
450
400
350
300
250
200
150
100
50
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 10.

TABLE 14.—*Monthly storage holdings of dry salt pork during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	252,933,726	51.6	+88,488,079	+35.0
February	341,421,805	69.6	+61,312,128	+18.0
March	402,733,933	82.2	+46,687,509	+11.6
April	449,421,442	91.7	+21,600,726	+ 4.8
May	471,022,168	96.1	+19,189,137	+ 4.0
June	490,211,305	100.0	−93,310,896	−19.0
July	396,900,409	81.0	−27,689,710	− 7.0
August	369,210,699	75.3	−35,663,271	− 9.7
September	333,547,428	68.0	−49,904,473	−15.0
October	283,642,955	57.9	−37,519,832	−13.2
November	246,123,123	50.2	+36,915,885	+15.0
December	283,039,008	57.7	+70,809,373	+25.0

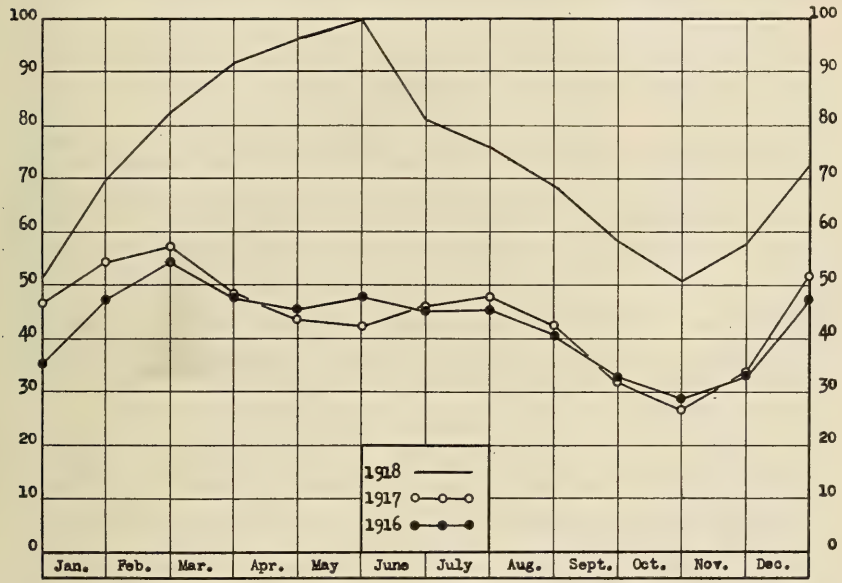

FIG. 11.—Relative monthly storage holdings of dry salt pork during 1916, 1917, and 1918. Base 100 equals holdings on June 1, 1918.

The holdings increased during the months of January to May, inclusive, then decreased until November 1. Increases again occurred during November and December. The greatest increase was in January, amounting to 88,488,079 pounds, while the largest decrease amounted to 93,310,896 pounds in June. The smallest amount reported for the year was held on November 1, the holdings of that date being approximately one-half of the June 1 holdings. Table 14 shows the monthly holdings, increases, and decreases, and figure 10 is a graphic presentation of the monthly stocks during 1918.

The holdings reported for each month during 1918 are tabulated in Table 15 together with a comparison of the stocks of each month with those of the same date in 1917. Each month's holdings greatly exceeded the quantities reported for the same month in 1917. The increase varied from about 33,000,000 pounds or 16 per cent on January 1 to 65,000,000 or 125 per cent on June 1. Figure 11 is a graphic comparison of the storage holdings and movement during the years of 1916 to 1918, inclusive. It shows very clearly the comparative uniformity of holdings and movement during 1916 and 1917 and the abnormally large stocks held during 1918. The peak load of the previous two years came on March 1, while in 1918 the stocks did not reach their highest point until June 1.

TABLE 15.—*Monthly cold storage holdings of dry salt pork during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	421	252,633,335	338	200,998,361	233,087,576	+ 16.0
February	446	341,391,805	379	228,423,710	316,763,231	+ 38.7
March	466	402,683,433	401	259,058,920	381,854,062	+ 47.4
April	482	449,287,442	411	234,395,683	417,733,224	+ 78.2
May	485	471,092,198	431	219,818,561	455,908,772	+107.4
June	480	490,193,305	436	213,801,699	481,039,210	+125.0
July	485	396,170,409	436	224,812,596	385,181,429	+ 71.3
August	485	369,902,599	437	231,905,289	364,349,447	+ 57.1
September	478	333,547,428	432	195,677,563	330,329,390	+ 68.8
October	481	283,642,955	430	143,318,686	278,984,296	+ 94.7
November	466	246,848,522	419	110,652,298	237,270,754	+114.4
December	449	282,821,332	413	150,882,126	277,456,636	+ 83.9

PICKLED PORK.

The term pickled pork includes sweet pickled, plain brine, and barreled pork. The reports as received include meats in process of curing, in both cold storage and packing houses, as well as meats actually cured.

TABLE 16.—*Storage holdings of pickled pork as reported on May 1, 1918.*

Section.	Reported for May 1, 1918.			Comparison with May 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	May 1, 1917.	May 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	33	28,203,215	6.9	30	27,020,113	28,188,948	+ 4.3
Middle Atlantic	127	30,071,229	7.4	119	30,580,537	29,190,699	− 4.5
South Atlantic	54	8,449,654	2.1	46	7,150,383	7,627,770	+ 6.7
N. Central (east)	151	165,806,233	40.8	140	136,865,142	165,416,592	+ 20.9
N. Central (west)	80	144,694,088	35.6	78	141,948,289	142,766,738	+ 0.6
South Central	28	11,606,658	2.9	25	19,389,320	11,335,068	− 41.5
Western (north)	37	5,503,784	1.3	35	7,006,398	5,494,084	− 21.6
Western (south)	42	12,024,986	3.0	38	11,275,566	11,668,489	+ 3.5
Total	552	406,359,847	100.0	511	381,235,748	401,688,388	+ 5.4

On May 1, 552 concerns reported total stocks of 406,359,847 pounds. It is estimated that the holdings of the two houses that did not report on that date amounted to 12,000 pounds. The concerns located in the North Central section east of the Mississippi held 40.8 per cent of the stocks of that date, and those in the North Central West section 35.6 per cent. These two sections held more than 70 per cent of the holdings of each month. Chicago concerns held 22.5 per cent of the May 1 stocks.

TABLE 17.—*Monthly storage holdings of pickled pork during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	269,003,222	66.2	+53,001,086	+19.7
February	322,004,308	79.2	+47,009,951	+14.6
March	369,014,259	90.8	+35,301,183	+ 9.6
April	404,315,442	99.5	+ 2,056,405	+ 0.5
May	406,371,847	100.0	− 8,088,926	− 1.9
June	398,282,921	98.0	−20,111,038	− 5.0
July	378,171,883	93.1	− 3,182,451	− 0.8
August	374,989,432	92.3	−59,570,801	−15.9
September	315,418,631	77.6	−65,606,670	−20.8
October	249,811,961	61.5	−18,061,883	− 7.2
November	231,750,078	57.0	+11,629,977	+ 5.0
December	243,380,055	60.0	+58,996,612	+24.2

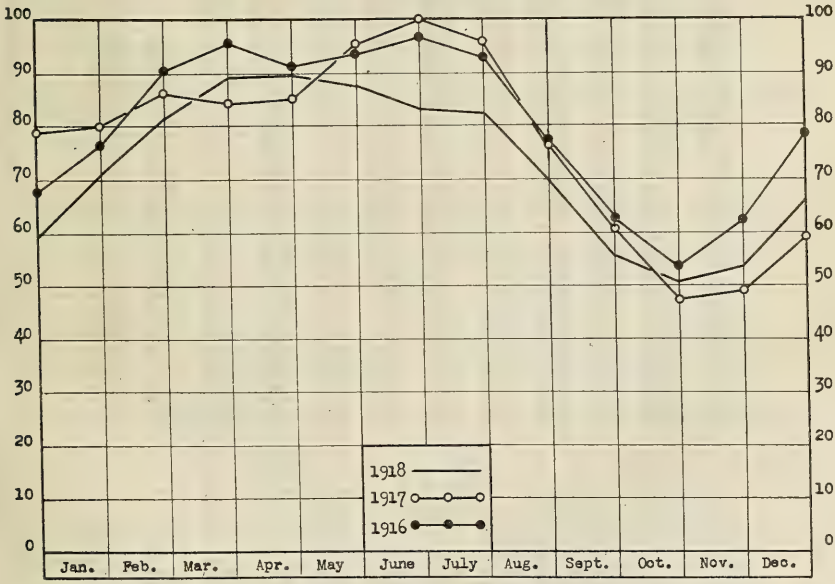

FIG. 12.—Relative monthly storage holdings of pickled pork during 1916, 1917, and 1918. Base 100 equals holdings on July 1, 1917

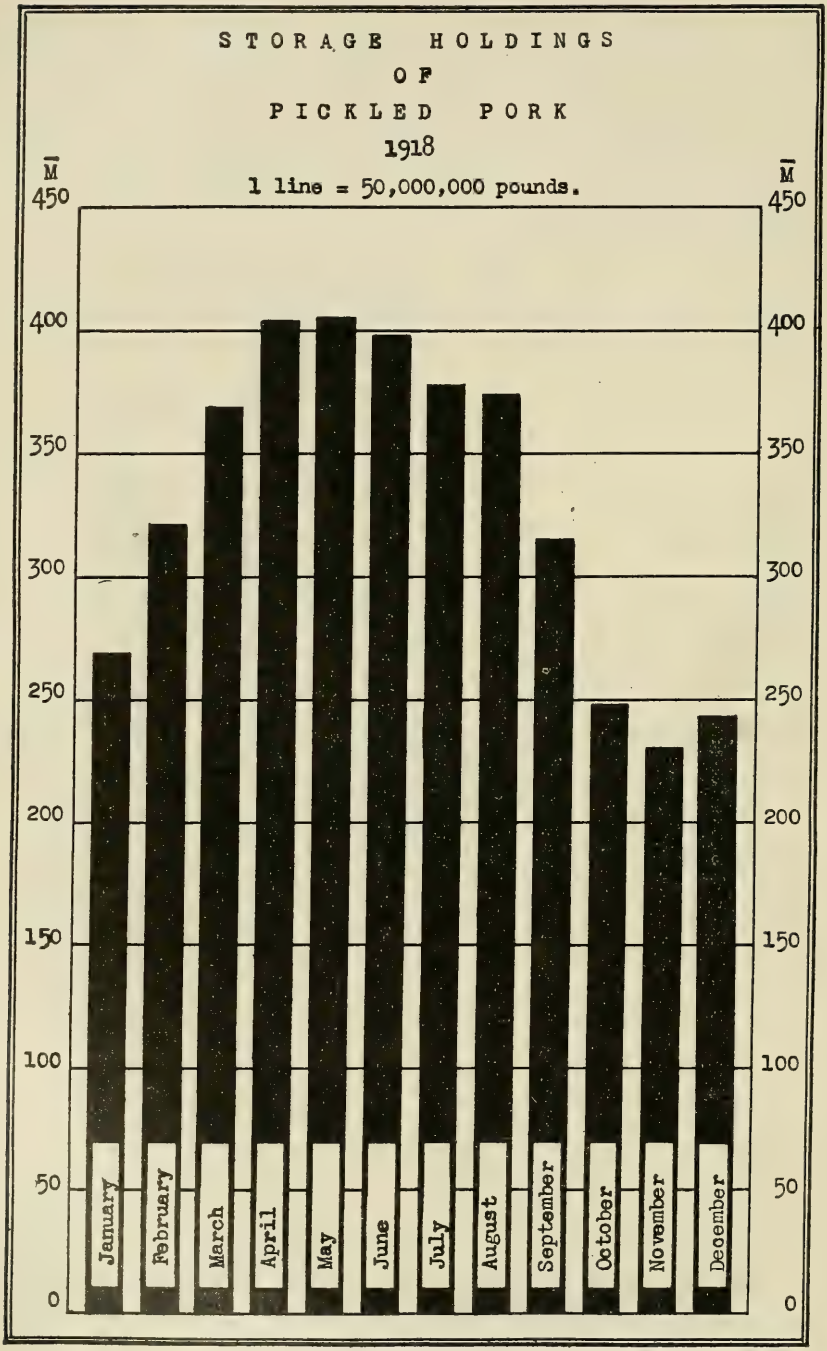
STORAGE HOLDINGS
OF
PICKLED PORK
1918
1 line = 50,000,000 pounds.
M
450
400
350
300
250
200
150
100
50
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 13.

TABLE 18.—*Monthly storage holdings of pickled pork during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	509	267,606,693	412	307,478,279	244,588,225	−20.5
February	530	321,586,508	455	348,269,159	298,174,603	−14.4
March	545	368,970,759	480	378,846,509	350,997,846	− 7.4
April	562	403,715,442	499	362,931,415	378,870,909	+ 4.4
May	552	406,359,847	511	381,235,748	401,688,388	+ 5.4
June	549	398,335,656	500	403,185,454	390,849,656	− 3.1
July	556	377,649,383	517	412,810,182	358,122,273	−13.2
August	561	375,476,032	523	403,704,023	367,987,377	− 8.8
September	558	315,381,931	524	328,943,256	315,268,734	− 4.2
October	553	249,782,261	515	252,151,967	247,041,882	− 2.0
November	539	232,450,830	497	192,883,562	225,881,961	+17.1
December	529	242,926,007	504	204,906,837	239,690,776	+17.0

The monthly holdings reported during 1918 were apparently quite normal, varying little from those reported for the previous two years. There was an increase on May 1 of 5.4 per cent over the stocks held on the same date in 1917.

The holdings of January 1, 1918, were 20.5 per cent less than in 1917, while the December 1 holdings were 17 per cent more. The increases and decreases over last year's holdings are given in Table 18 while the comparative holdings and movement for the years of 1916 to 1918, inclusive, are shown in figure 12.

The holdings increased monthly from January 1 to May 1, then decreased until November 1, when they reached the lowest point of the year. The stocks at this time were 43 per cent less than on May 1. The largest monthly increase occurred in December, amounting to 58,996,612 pounds. The largest decrease was 65,606,670 pounds during September. Figure 13 furnishes a graphic comparison of monthly stocks during 1918.

LARD.

The lard holdings reported to the Bureau of Markets include all prime steam, kettle rendered, neutral, and other pure lard, both bulk and package. They do not include lard compounds. The information received covers the lard stored in both public and private cold storage warehouses and in packing houses.

TABLE 19.—*Storage holdings of lard as reported on July 1, 1918.*

Section.	Reported for July 1, 1918.			Comparison with July 1, 1917.			
	Storages reporting.	Holdings reported.	Percentage of total holdings.	Storages reporting on both dates.	July 1, 1917.	July 1, 1918.	Increase or decrease.
	Number.	*Pounds.*	*Per cent.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
New England	33	17,472,114	16.4	31	10,838,138	17,237,934	+ 59.0
Middle Atlantic	130	9,062,386	8.5	123	7,678,223	8,710,658	+ 13.4
South Atlantic	60	1,996,998	1.9	54	2,131,033	1,811,506	− 15.0
N. Central (east)	166	41,698,657	39.1	151	44,685,836	40,832,076	− 8.6
N. Central (west)	87	27,550,913	25.9	86	20,543,348	27,539,663	+ 34.1
South Central	52	2,210,146	2.1	48	2,714,231	2,150,045	− 20.8
Western (north)	35	2,766,280	2.6	34	2,846,720	2,678,492	− 5.9
Western (south)	45	3,733,462	3.5	37	3,759,428	3,539,416	− 5.9
Total	608	106,490,956	100.0	564	95,196,957	104,499,790	+ 9.8

On July 1, 1918, 608 concerns reported total stocks of 106,490,956 pounds. All cold storages and packing houses on the list of the Bureau of Markets reported their holdings for that date. The reports of 564 concerns indicated that the holdings of that date were 9.8 per cent more than on the same date in 1917. Sixty-five per cent of the holdings of July 1 were in the North Central States and 16.4 per cent in the New England States. One-fourth of the stocks were in the city of Chicago and one-twentieth in Greater New York.

TABLE 20.—*Monthly storage holdings of lard during 1918, and increase or decrease during each month.*

Month.	Holdings on first of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	54,539,198	51.2	+ 4,771,244	+ 8.7
February	59,310,442	55.7	+ 6,044,811	+10.2
March	65,355,253	61.4	+24,498,566	+37.5
April	89,853,819	84.4	+13,519,583	+15.0
May	103,373,402	97.1	+ 2,820,922	+27.3
June	106,194,324	99.7	+ 296,632	+ 0.3
July	106,490,956	100.0	− 4,695,964	− 4.4
August	101,794,992	95.6	+ 2,840,569	+ 2.8
September	104,635,561	98.3	−14,409,536	−13.8
October	90,226,025	84.7	−14,486,844	−16.1
November	75,739,181	71.1	+ 5,931,368	+ 7.8
December	81,670,549	76.5	+22,294,785	+27.3

The stocks reported monthly, plus an estimate of the holdings of the unreported concerns, are tabulated in Table 20 together with the actual increases and decreases in holdings during each month. The greatest increase is shown during March and the greatest decrease during October. The smallest quantity held during the year was reported on January 1, the holdings of that date being 51.2 per cent of the July 1 holdings. After that date the lowest point reached was on November 1, which showed a decrease of 28.9 per cent from the maximum holdings on July 1.

TABLE 21.—*Monthly storage holdings of lard during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	525	54,190,596	414	80,977,065	49,253,023	−39.2
February	544	59,114,842	445	86,207,792	56,227,827	−34.8
March	562	65,308,753	479	88,459,714	62,931,026	−28.9
April	576	89,853,819	497	65,178,669	85,616,150	+31.4
May	586	103,366,602	518	61,640,427	97,716,151	+58.5
June	598	106,244,670	534	72,365,145	103,528,896	+43.1
July	608	106,490,956	564	95,196,957	104,499,790	+ 9.8
August	602	101,810,092	543	112,248,614	98,745,935	−12.0
September	611	104,619,841	564	102,171,730	102,658,110	+ 0.5
October	607	90,211,400	553	69,928,942	87,165,483	+24.6
November	594	76,226,395	548	37,095,455	73,464,701	+98.0
December	576	81,467,977	546	44,367,243	79,764,083	+79.8

As shown by the curves in figure 14, representing the holdings and increases or decreases during the years of 1916 to 1918, inclusive, there does not appear to be any great regularity of movement of lard to and from storage. In 1916 the largest quantity stored at any one time during the year was reported on May 1. In 1917 the largest stocks were held on August 1, while in 1918 the peak load occurred on July 1. A comparison of the holdings of each month with those of 1917 is given in Table 21. Figure 15 illustrates the relative quantities held on the first of each month during the year.

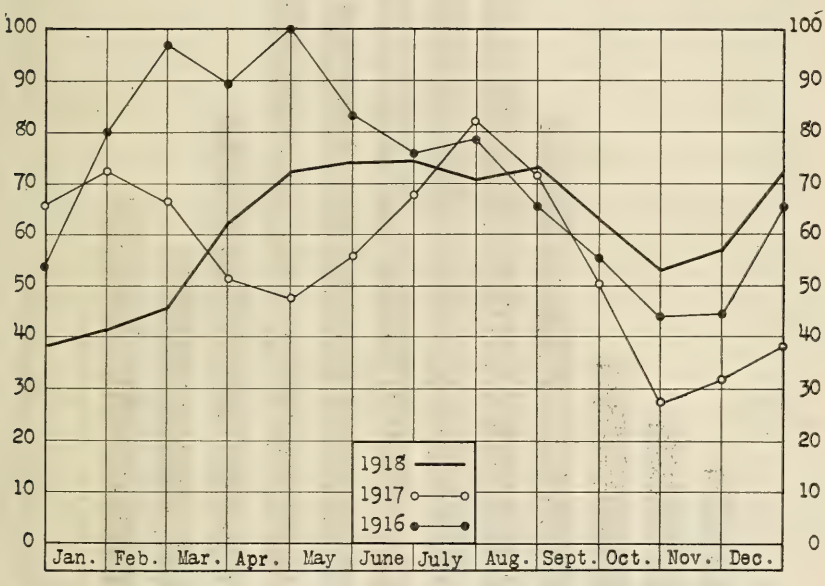

FIG. 14.—Relative monthly cold storage holdings of lard during 1916, 1917, and 1918. Base 100 equals holdings on May 1, 1916.

REVIEW OF THE 1918 COLD STORAGE HOLDINGS OF FROZEN FISH.

The first report of the Bureau of Markets showing the holdings of frozen fish, cured herring, and mild cured salmon was issued on October 15, 1917. These reports cover 22 varieties of frozen fish, all other varieties being grouped under the heading of miscellaneous frozen fish. Among the varieties included in the miscellaneous group are albacore, bonito, burbot, catfish, eels, flounder, German and buffalo carp, horse mackerel, perch, pike, pickerel, pompano, red snapper, sheepshead, spanish mackerel, swordfish, tilefish, tuna, all kinds of salt and fresh water bass, except sea bass, and soft crabs and bay scallops.

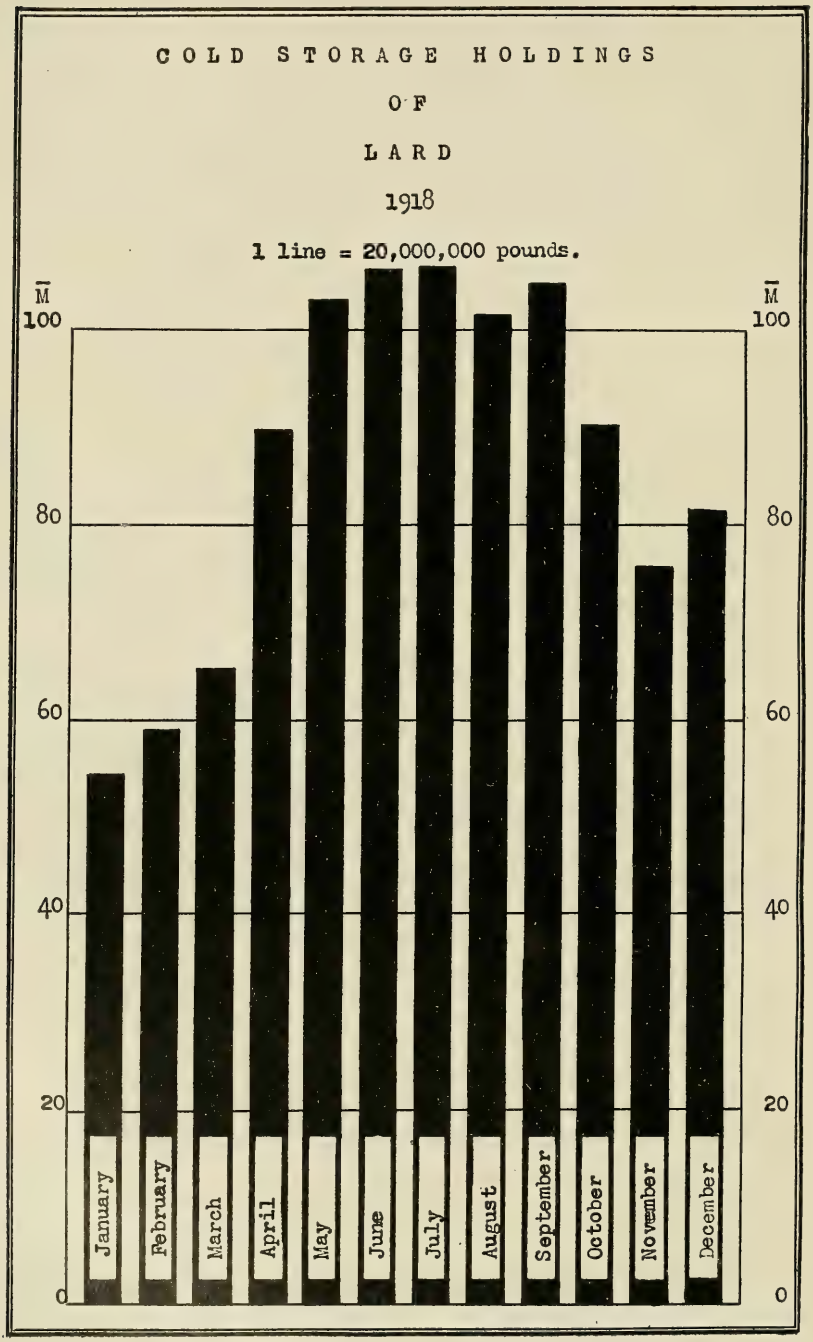
COLD STORAGE HOLDINGS
OF
LARD
1918
1 line = 20,000,000 pounds.
M
100
80
60
40
20
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 15.

In order to relieve the congestion of the work of compilations at the first of the month, incidental to the preparation of other storage reports, and thus enable the Bureau to handle its work more economically, the reports for fish are obtained for the fifteenth of each month.

When these reports were begun, many firms did not have sufficient records to enable them to furnish exact data. For this reason the reports for the months of October to December, inclusive, are omitted from this review. However, a very accurate tabulation of the stocks for these dates is found in the tables comparing the holdings of 1918 with those of 1917.

Exceptionally complete reports have been obtained from the warehouses storing fish. Reports have been received from every firm on the list of the Bureau for every month during 1918 except that one firm failed to report its holdings for July. For several months reports from a few firms were received too late to be included in the report for that month. Their holdings are included in the revised tabulations in this bulletin.

The descriptions of the different varieties of fish quoted hereafter are selected from the report of the Bureau of the Census on Fisheries of the United States, 1908.

BLUEFISH.

This is "a very gamy food fish found on the Atlantic and Gulf Coasts. On the coast of the New England and Middle States, it is called 'blue fish'; in Rhode Island, 'horse mackerel'; south of Cape Hatteras, 'skip jack'; in North Carolina, Virginia, and Maryland, 'tailor' and 'greenfish'; in the Gulf of Mexico, 'blue fish.' They vary in weight from 1 to 20 pounds, according to the season and locality. Large numbers are caught during the summer with nets, traps, seines, and hand lines."

On January 15, 1918, the reports to the Bureau showed stocks of 156,664 pounds. The holdings decreased until July 1, when less than 25,000 pounds remained in cold storage. There was a slight increase from July 15 to August 15, but the most of the holdings of the season were placed in cold storage between August 15 and September 15. The increase in stocks during that time amounted to 176,753 pounds. The largest quantity reported during the year was held on October 15, and amounted to a little more than 275,000 pounds. This quantity was more than 50 per cent greater than the holdings of the same date in 1917. The quantity of bluefish frozen during 1918 amounted to approximately one-third of one per cent of the total fish frozen during the year.

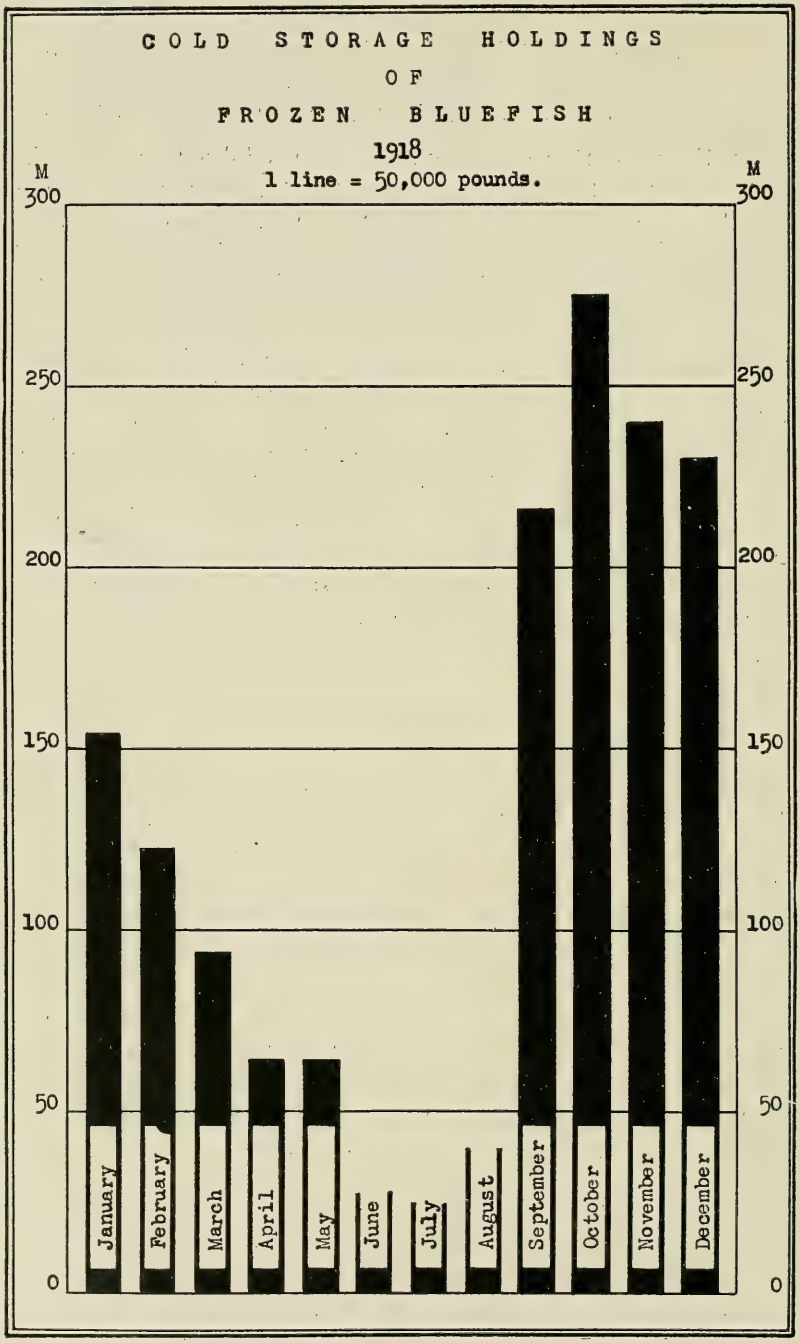
COLD STORAGE HOLDINGS
OF
FROZEN BLUEFISH
1918
1 line = 50,000 pounds.
M
300
250
200
150
100
50
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 16.

TABLE 22.—*Monthly cold storage holdings of frozen bluefish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	156,664	56.9	− 34,122	− 21.8
February	122,542	44.5	− 28,532	− 23.3
March	94,010	34.1	− 29,594	− 31.5
April	64,416	23.4	+ 170	+ 0.3
May	64,586	23.5	− 37,183	− 57.6
June	27,403	10.0	− 2,433	− 8.9
July	24,970	9.1	+ 14,362	+ 57.5
August	39,332	14.3	+176,753	+449.4
September	216,085	78.5	+ 59,248	+ 27.4
October	275,333	100.0	− 36,110	− 13.1
November	239,223	86.9	− 9,371	− 3.9
December	229,852	83.5	+ 4,582	+ 2.0

TABLE 23.—*Monthly cold storage holdings of frozen bluefish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	39	156,664	30	242,037	124,688	− 48.5
February	39	122,542	30	15,980	5,356	− 66.5
March	41	94,010	33	105,586	84,860	− 19.6
April	37	64,416	31	45,516	59,847	+ 31.5
May	30	64,586	24	15,028	43,270	+187.9
June	25	27,403	18	79,010	22,621	− 71.4
July	26	24,970	21	124,867	21,929	− 82.4
August	26	39,332	22	83,845	37,857	− 54.8
September	27	216,085	19	43,451	166,919	+284.2
October	35	275,333	30	172,732	265,328	+ 53.6
November	35	239,223	32	209,430	237,407	+ 13.4
December	34	229,852	33	175,392	224,852	+ 28.2

BUTTERFISH.

This is "a food fish found on the Atlantic Coast from Mexico to Florida. It is called 'butterfish' in Massachusetts and New York, 'harvestfish' in New Jersey, 'dollarfish' in Maine, 'sheepshead' and 'skipjack' about Cape Cod, 'pumpkin-seed' in Connecticut, and 'starfish' at Norfolk. It has an average length of 7 to 8 inches and is caught in traps and pounds."

On January 15, 1918, the reports showed 875,585 pounds of frozen butterfish stored. These holdings were reduced to 97,113 by April 15. The holdings then increased until November 15, except for a slight decrease of a little less than 6,000 pounds from August 15 to September 15. On November 15, the holdings amounted to 1,308,423 pounds, which was 11.2 per cent less than the stocks of the same date in 1917.

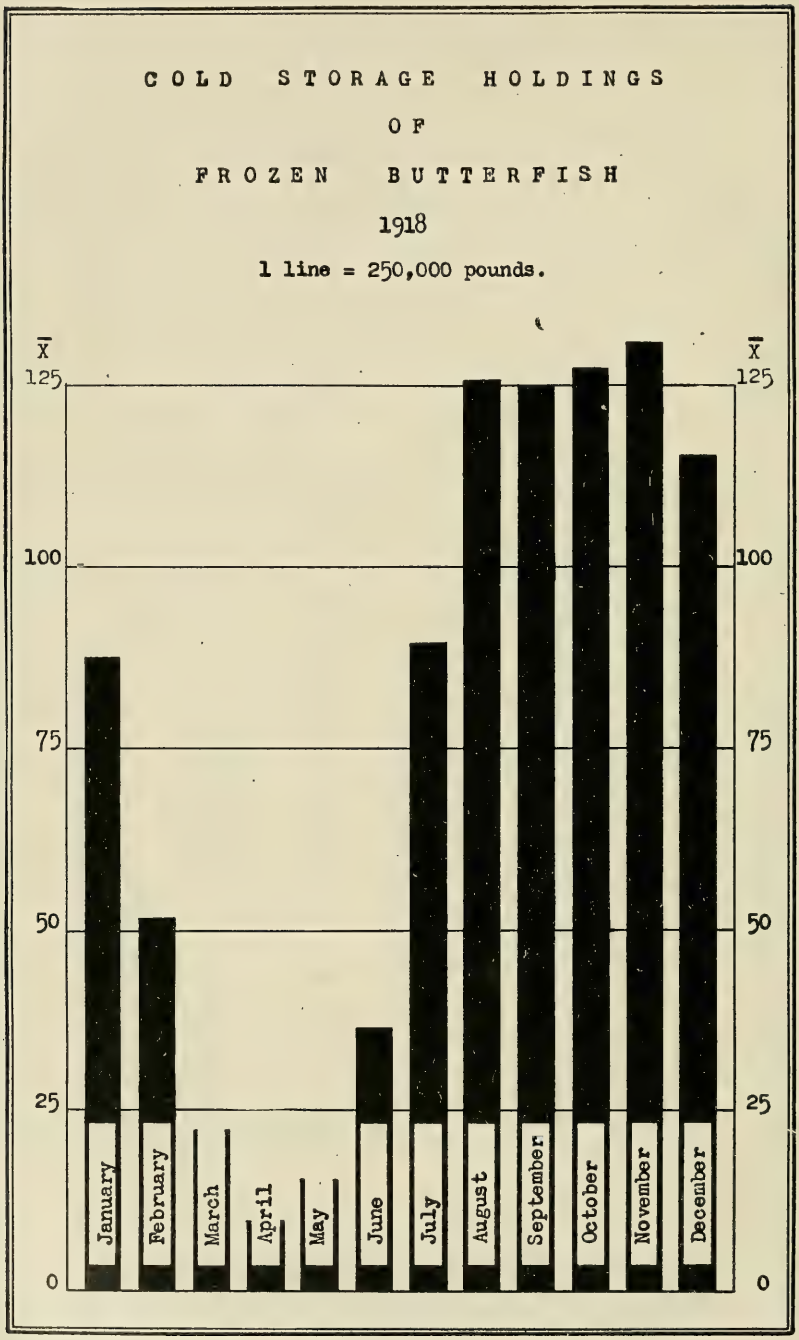
COLD STORAGE HOLDINGS
OF
FROZEN BUTTERFISH
1918
1 line = 250,000 pounds.
X̄
125
100
75
50
25
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 17.

TABLE 24.—*Monthly cold storage holdings of frozen butterfish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	875,585	66.9	−359,725	− 41.1
February	515,860	39.4	−295,692	− 57.3
March	220,168	16.8	−123,055	− 55.9
April	97,113	7.4	+ 58,577	+ 60.3
May	155,690	11.9	+208,586	+134.0
June	364,276	27.8	+528,270	+145.0
July	892,546	68.2	+363,351	+ 40.7
August	1,255,897	96.0	− 5,616	− 0.4
September	1,250,281	95.6	+ 20,765	+ 1.7
October	1,271,046	97.1	+ 37,377	+ 2.9
November	1,308,423	100.0	−154,366	− 11.8
December	1,154,057	88.2	−241,963	− 21.0

TABLE 25.—*Monthly cold storage holdings of frozen butterfish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	48	875,585	40	867,268	596,422	−31.2
February	49	515,860	41	271,259	112,126	−58.7
March	51	220,168	40	232,270	158,531	−31.7
April	50	97,113	40	75,665	66,889	−11.6
May	34	155,690	26	34,054	62,088	+82.3
June	21	364,276	15	580,132	113,996	−80.3
July	28	892,546	22	1,087,877	639,344	−41.2
August	33	1,255,897	27	1,166,258	798,355	−31.5
September	33	1,250,281	27	1,142,620	732,324	−35.9
October	35	1,271,046	33	1,419,388	1,083,329	−23.7
November	38	1,308,423	37	1,471,552	1,306,723	−11.2
December	41	1,154,057	40	1,126,925	1,153,843	+ 2.4

CISCOES.

These "are one of the lesser white fishes found in the Great Lakes and neighboring waters. Other names are 'lake herring' and 'Michigan herring.' The usual length is a little more than 12 inches. It belongs to the salmon family. The name is also applied to a related species of less economic importance."

On January 15, 1918, the reports of the Bureau showed stocks of 7,291,759 pounds of frozen ciscoes in cold storage. A comparatively small number of warehouses reported their holdings for both 1918 and 1917, but their reports indicate that the stocks were 178.8 per cent greater than those of the previous year. The holdings decreased until June 15, when 1,307,078 pounds remained in cold storage. From July 15 to September 15 the holdings were increased by more than 3,000,000 pounds. An increase of 1,826,940 pounds was also shown during the period from November 15 to December 15. By December 15 the stocks amounted to 6,010,152 pounds.


COLD STORAGE HOLDINGS
OF
FROZEN CISCOES
1918
1 line = 1,000,000 pounds.
M
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 18.

TABLE 26.—*Monthly cold storage holdings of frozen ciscoes during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	7,291,759	100.0	−2,812,503	− 38.6
February	4,479,256	61.4	−1,665,005	− 37.2
March	2,814,251	38.6	− 590,085	− 21.0
April	2,224,166	30.5	− 469,042	− 21.1
May	1,755,124	24.1	− 448,046	− 25.5
June	1,307,078	17.9	+ 91,868	+ 7.0
July	1,398,946	19.2	+1,756,855	+125.6
August	3,155,801	43.3	+1,334,688	+ 42.3
September	4,490,489	61.6	− 638,014	− 14.2
October	3,852,475	52.8	+ 330,737	+ 8.6
November	4,183,212	57.4	+1,826,940	+ 43.7
December	6,010,152	82.4	− 915,344	− 15.2

TABLE 27.—*Monthly cold storage holdings of frozen ciscoes during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	69	7,291,759	48	1,824,299	5,086,286	+ 178.8
February	69	4,479,256	49	488,827	1,926,919	+ 294.2
March	69	2,814,251	53	486,093	2,007,479	+ 313.0
April	65	2,224,166	51	228,979	1,488,695	+ 550.1
May	47	1,755,124	34	64,688	1,216,798	+1781.0
June	43	1,307,078	30	172,992	770,497	+ 345.4
July	44	1,393,946	32	261,990	1,054,768	+ 302.6
August	49	3,155,801	37	1,018,432	2,699,256	+ 165.0
September	54	4,490,489	41	2,860,274	3,890,162	+ 36.0
October	54	3,852,475	46	4,275,436	3,624,374	− 15.2
November	59	4,183,212	57	5,837,282	4,067,123	− 30.3
December	63	6,010,152	61	9,455,063	5,917,686	− 37.4

COD, HAKE, POLLACK, HADDOCK.

The cod is "one of the most important food fishes in the United States. It is caught most extensively along the coasts of the Middle States, New England and British America. It varies in weight from 3 to 75 pounds. It is caught with hand lines, trawls, nets, etc., and is sold fresh, pickled, salted, and dried." The reports of the Bureau of Markets deal only with the quantity that is frozen. With this variety of fish the reports also include the stocks of hake, pollack, and haddock that are frozen. "The so-called hakes are not hakes, but are food fish found on the Atlantic Coast from Newfoundland to Cape Hatteras. The different species are known as 'old English hake,' 'squirrel hake,' 'white hake,' 'king hake,' 'codling,' etc. They are often prepared under the trade name of boneless fish. They average from 1½ to 2 feet in length and 3 to 8 pounds in weight, and are caught near muddy bottoms with trawls and hand lines and in weirs and traps."

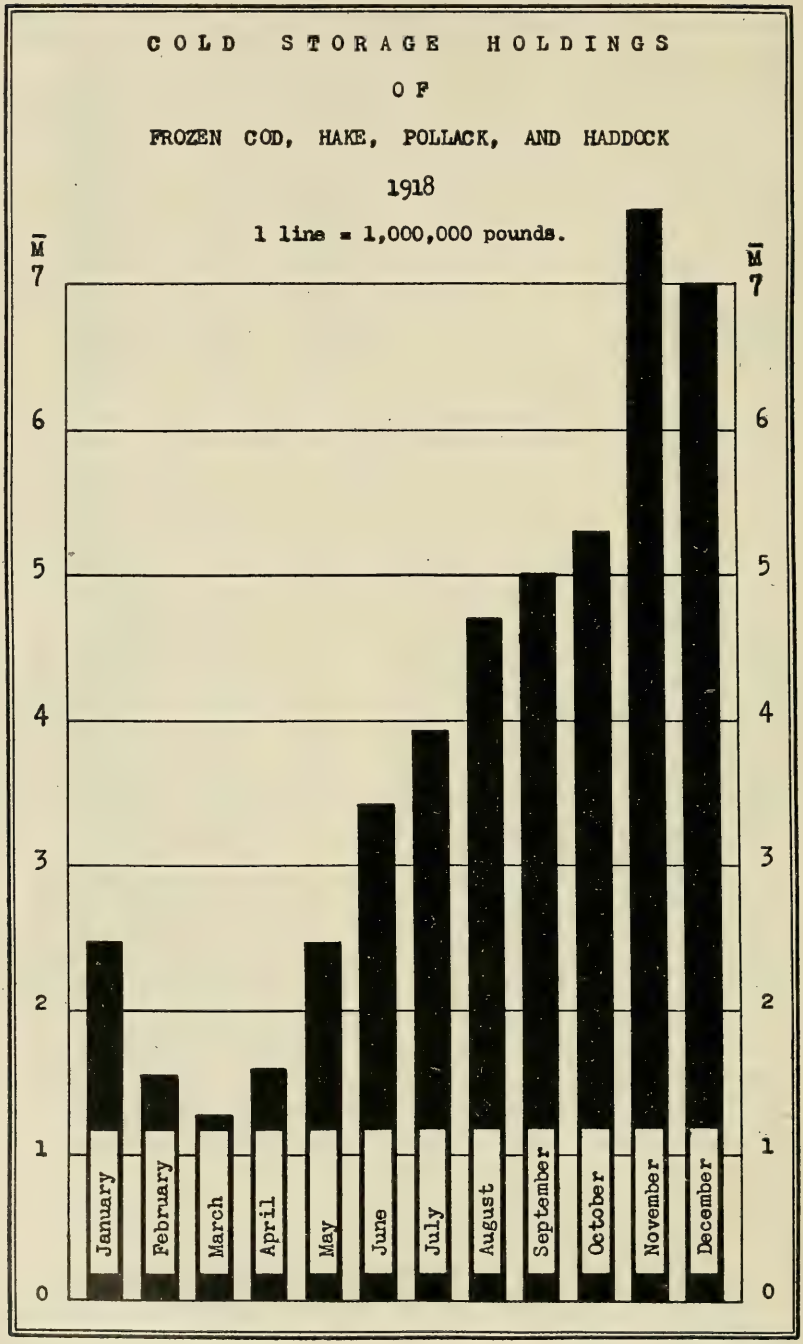
COLD STORAGE HOLDINGS
OF
FROZEN COD, HAKE, POLLACK, AND HADDOCK
1918
1 line = 1,000,000 pounds.
M
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 19.

Pollack is "a food fish found mainly off the New England coast. It sometimes occurs as far south as Virginia. The average weight is about 10 pounds."

The haddock is "a food fish found in the Atlantic north of the Delaware capes and is called 'dickie' in some localities. It averages in weight from 4 to 6 pounds. It is extensively caught for a fresh food fish and is also salted, pickled, and dried. When slack-salted and smoked, it is sold under the name of 'haddie.'"

The reports received for January 15 showed stocks of 2,488,872 pounds. The holdings increased until November 15, when the reports showed holdings of 7,509,512 pounds. This was 77.3 per cent more than was held on the same date in 1917. The quantity of these varieties of fish that was frozen during 1918 amounted to more than 15 per cent of the total fish frozen during the year.

TABLE 28.—*Monthly cold storage holdings of frozen cod, hake, pollack, and haddock during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	2,488,872	33.1	− 935,052	−37.6
February	1,553,820	20.7	− 269,216	−17.3
March	1,284,604	17.1	+ 306,085	+23.8
April	1,590,689	21.2	+ 859,900	+54.1
May	2,450,589	32.6	+ 954,365	+38.9
June	3,404,954	45.3	+ 502,747	+14.8
July	3,907,701	52.0	+ 785,297	+20.1
August	4,692,998	62.5	+ 321,458	+ 6.8
September	5,014,456	66.8	+ 279,705	+ 5.6
October	5,294,161	70.5	+2,215,351	+41.8
November	7,509,512	100.0	− 504,768	− 6.7
December	7,004,744	93.3	− 385,737	− 5.5

TABLE 29.—*Monthly cold storage holdings of frozen cod, hake, pollack, and haddock during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reproting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	89	2,488,872	71	1,189,234	1,815,041	+ 52.6
February	101	1,553,820	80	556,647	639,757	+ 14.9
March	105	1,284,604	85	482,010	780,898	+ 62.0
April	107	1,590,689	88	666,334	1,279,577	+ 92.0
May	85	2,450,589	71	1,104,220	2,074,973	+ 87.9
June	84	3,404,954	70	1,993,803	2,553,971	+ 28.1
July	91	3,907,701	75	2,292,478	3,286,513	+ 43.4
August	94	4,692,998	78	1,373,992	3,978,977	+189.6
September	90	5,014,456	72	1,826,221	4,253,596	+132.9
October	91	5,294,161	83	2,972,331	4,958,035	+ 66.8
November	99	7,509,512	94	3,778,260	6,700,370	+ 77.3
December	105	7,004,744	102	4,503,718	6,666,832	+ 48.0

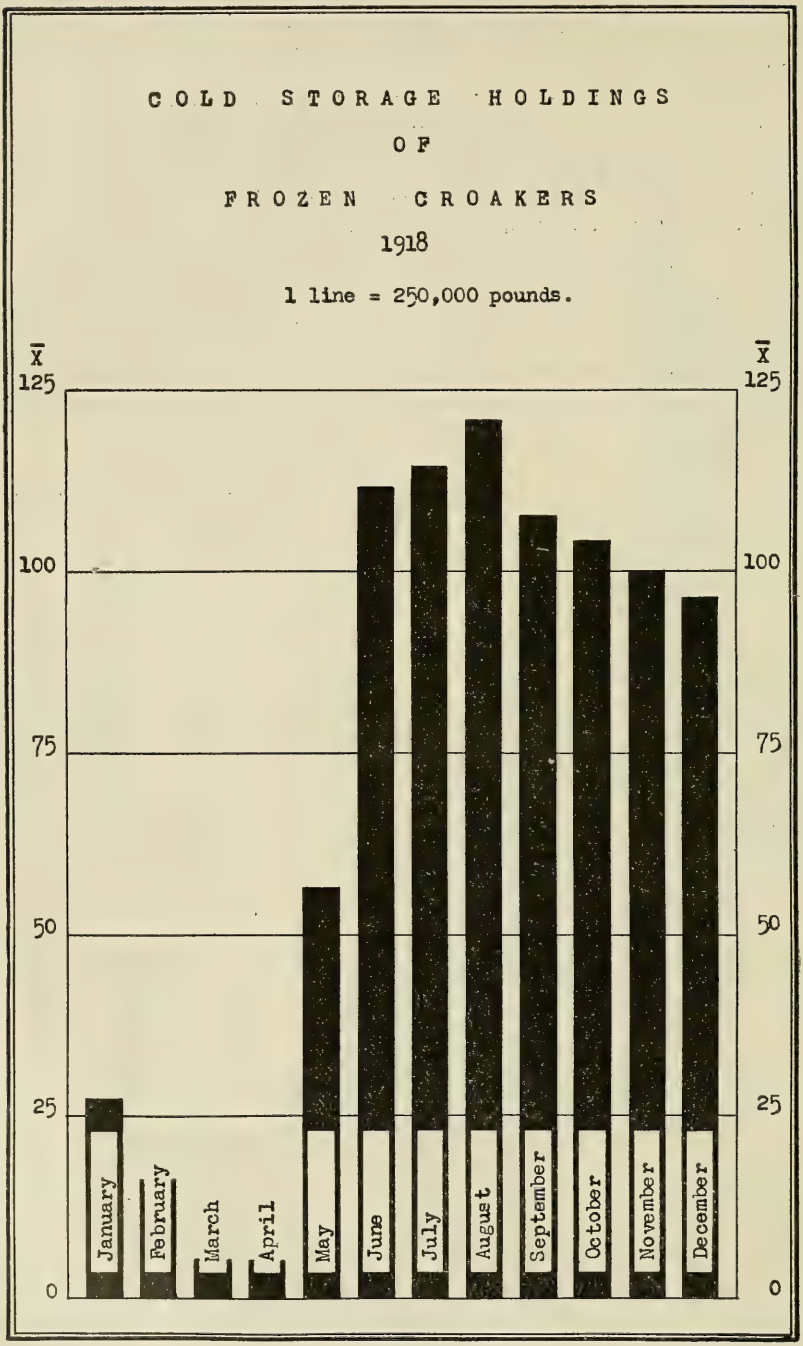
COLD STORAGE HOLDINGS
OF
FROZEN CROAKERS
1918
1 line = 250,000 pounds.
X̄
125
100
75
50
25
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 20.

CROAKERS.

This is "a food fish found mostly in the South, but sometimes caught as far north as New York. Local names are 'crocus' and 'ronco.' It averages about 10 inches in length. Large quantities are caught in the Gulf with hand lines and seines."

On January 15, 1918, there were 274,333 pounds of frozen croakers in cold storage. The holdings decreased until April 15 and amounted to a little more than 50,000 pounds on that date. From the fifteenth of April to the fifteenth of June the holdings increased 1,064,909 pounds and by August 15 there were 1,209,305 pounds on hand. The stocks gradually decreased for the rest of the year. The holdings of August 15 were 64.5 per cent greater than on the same date in 1917.

TABLE 30.—*Monthly cold storage holdings of frozen croakers during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	274,333	22.7	−112,498	− 41.0
February	161,835	13.4	−105,411	− 65.1
March	56,424	4.7	− 5,278	− 9.4
April	51,146	4.2	+517,819	+1012.4
May	568,965	47.0	+547,090	+ 96.2
June	1,116,055	92.3	+ 27,067	+ 2.4
July	1,143,122	94.5	+ 66,183	+ 5.8
August	1,209,305	100.0	−129,443	− 10.7
September	1,079,862	89.3	− 37,155	− 3.4
October	1,042,707	86.2	− 36,669	− 3.5
November	1,006,038	83.2	− 42,200	− 4.2
December	963,838	79.7	−245,138	− 25.4

TABLE 31.—*Monthly cold storage holdings of frozen croakers during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	23	274,333	18	213,356	139,917	− 34.4
February	23	161,835	17	90,967	68,533	− 24.7
March	24	56,424	17	12,703	44,868	+253.2
April	20	51,146	14	17,556	26,568	+ 51.3
May	21	568,965	16	173,749	247,855	+ 42.7
June	19	1,116,055	13	174,793	484,348	+177.1
July	20	1,143,122	15	164,634	517,939	+214.6
August	22	1,209,305	17	324,652	534,002	+ 64.5
September	21	1,079,862	17	218,120	481,529	+120.8
October	19	1,042,707	16	330,175	775,590	+134.9
November	20	1,006,038	18	517,761	981,695	+ 89.6
December	22	963,838	22	425,660	963,838	+126.4

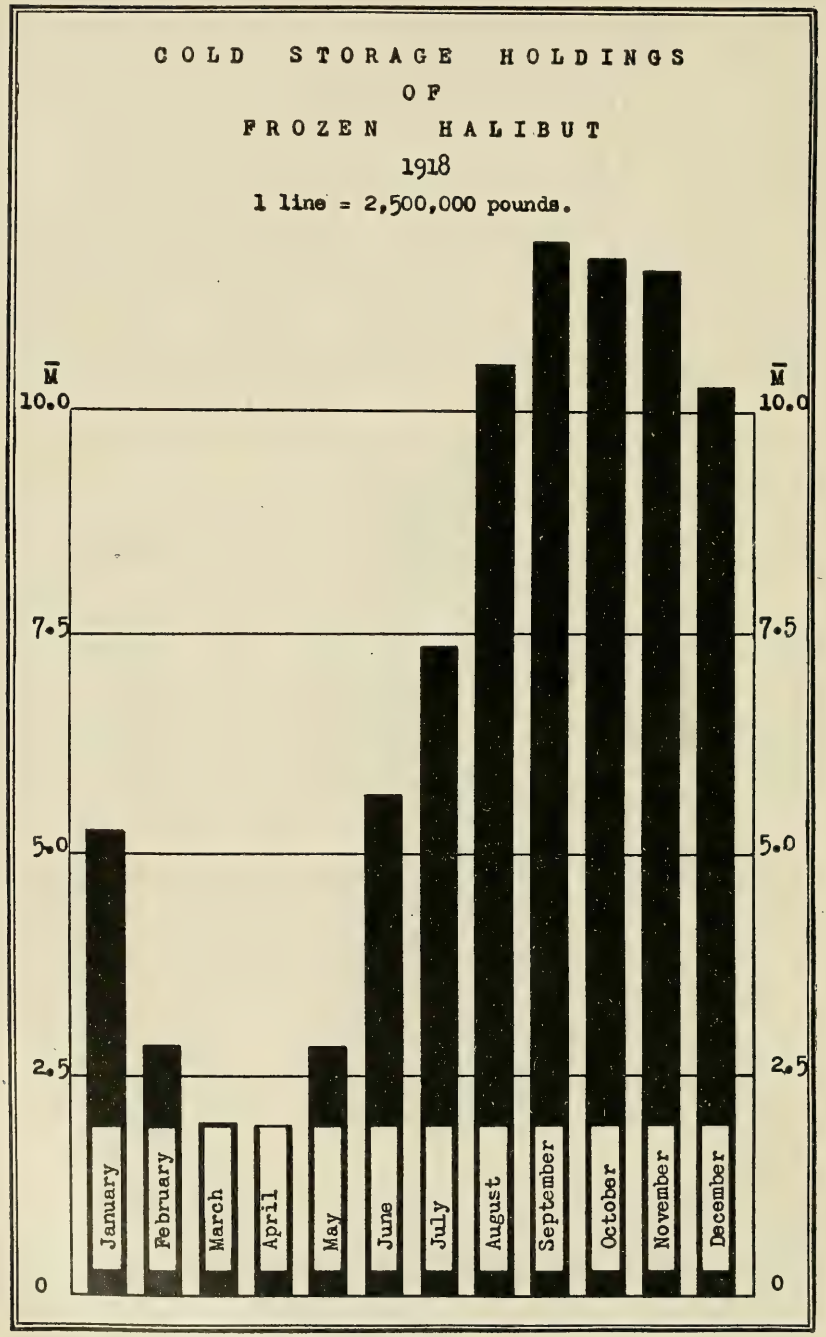
COLD STORAGE HOLDINGS
OF
FROZEN HALIBUT
1918
1 line = 2,500,000 pounds.
M
10.0
7.5
5.0
2.5
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 21.

HALIBUT.

This is "the largest and most valuable of the flat fishes and is found both in the North Atlantic and Pacific Oceans. It is one of the largest species used for food, sometimes weighing over 300 pounds. The average weight is from 50 to 75 pounds. It is caught with trawls and hand lines. There are three grades of halibut, the 'white,' which has its underside immaculate, is considered the best and brings the highest price; the 'gray' is blotched on the underside and sells for a third less; the 'sour' is tainted and brings only about a fourth as much as the 'white.' Small young fish weighing from 10 to 20 pounds are called 'chickens' and are greatly sought after by epicures."

On January 1, 1918, the stocks of frozen halibut amounted to 5,293,936 pounds and the holdings decreased to a little less than 2,000,000 pounds on April 15. The holdings then increased until September 15, when 11,946,117 pounds were reported. This amount was approximately 36.5 per cent more than the quantity stored the previous year.

TABLE 32.—*Monthly cold storage holdings of frozen halibut during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	5,293,936	44.3	−2,444,298	− 46.2
February	2,849,638	23.9	− 876,641	− 30.8
March	1,972,997	16.5	− 39,141	− 2.0
April	1,933,856	16.2	+ 895,455	+ 46.3
May	2,829,311	23.7	+2,855,510	+100.9
June	5,684,821	47.6	+1,686,841	+ 29.7
July	7,371,662	61.7	+3,165,205	+ 42,9
August	10,536,867	88.2	+1,409,250	+ 13.4
September	11,946,117	100.0	− 216,345	− 1.8
October	11,729,772	98.2	− 127,396	− 1.1
November	11,602,376	97.1	−1,301,675	− 11.2
December	10,300,701	86.2	−2,409,360	− 23.4

TABLE 33.—*Monthly cold storage holdings of frozen halibut during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	105	5,293,936	85	4,118,337	4,086,373	− 0.8
February	110	2,849,638	87	1,144,144	1,872,553	+63.7
March	113	1,972,997	89	1,003,764	1,000,077	− 0.4
April	109	1,933,856	89	1,156,983	1,195,219	+ 3.3
May	90	2,829,311	72	2,458,513	2,363,115	− 3.9
June	79	5,684,821	59	3,535,529	5,183,009	+46.6
July	81	7,371,662	62	4,611,518	5,707,822	+23.8
August	87	10,536,867	68	5,971,371	7,958,357	+33.3
September	78	11,946,117	60	6,749,648	9,213,890	+36.5
October	82	11,729,772	70	6,792,095	9,141,854	+34.6
November	88	11,602,376	80	8,544,995	10,973,624	+28.4
December	97	10,300,701	93	6,409,143	9,919,130	+54.8

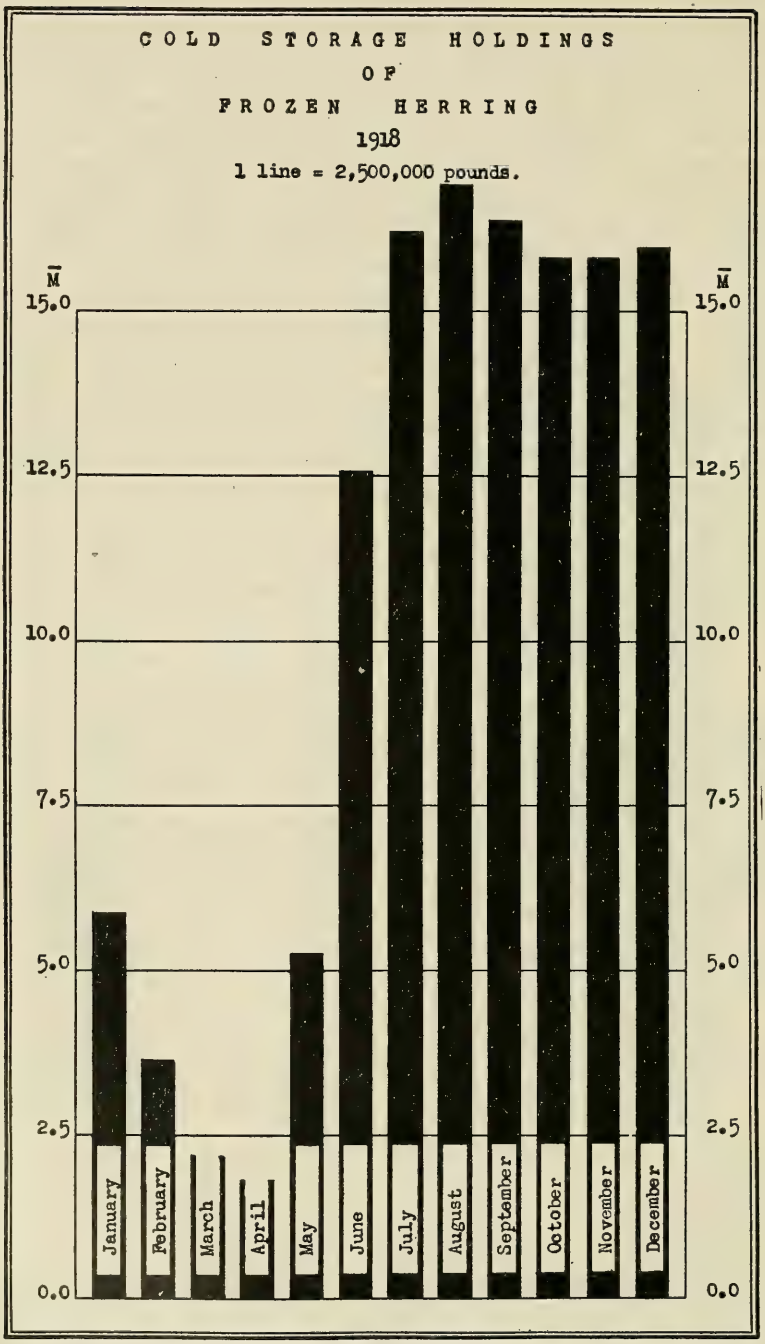
COLD STORAGE HOLDINGS
OF
FROZEN HERRING
1918
1 line = 2,500,000 pounds.
M
15.0
12.5
10.0
7.5
5.0
2.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 22.

HERRING.

This is "a very important food fish found in the North Atlantic as far south as Sandy Hook. It is never found in brackish or fresh water. 'Sperling' or 'brit' denote the differences in the age of the fish. They weigh from one-half to one pound, the average length being 10 inches. They are caught in pounds, traps, weirs, and gill nets, and by 'torching.' As a food fish they are used fresh, salted, pickled, smoked, and canned. They are also used extensively for bait in the cod, haddock, halibut, and hake fisheries."

With the herring are included alewives and bluebacks. The alewives "are found in waters adjacent to the sea. They are known along the Potomac as 'branch herring'; on the Albemarle, the 'big-eyed' and 'wall-eyed' herring; in North Carolina, the 'alewife'; and in Connecticut as 'ellwife' and 'ellwhop.' It appears in the rivers three or four weeks earlier than the 'glut herring' or the shad. Another species known as alewives is found from the Carolinas to the Gulf of Mexico. It is known in the Chesapeake Bay and the Albemarle Sound as 'glut herring'; in the Ogeechee River as 'English herring'; in the St. Johns River as 'herring'; and in Massachusetts and during later runs in the Rappahannock as the 'blueback.' It is also known as 'black-belly,' 'saw-belly,' and 'kyack.' It is less abundant than the other species and much less valuable as a food fish. Both species average about one-half pound in weight and 8 to 10 inches in length. They are caught in nets, seines, weirs, etc., and are of very great importance as a food fish."

The monthly reports from January 1 to April, inclusive, showed very small stocks of the frozen herring, varying from almost 6,000,000 pounds on January 15 to less than 2,000,000 on April 15. The greatest increase occurred from April 15 to July 15, amounting to more than 14,000,000 pounds. By August 15 there were 16,896,289 pounds frozen and in cold storage, which amount was almost one and one-half times greater than on the same date of the previous year. By December 15 the holdings had decreased only slightly and amounted to almost 16,000,000 pounds.

TABLE 34.—*Monthly cold storage holdings of frozen herring during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	5,891,359	34.9	−2,276,179	− 38.6
February	3,615,180	21.4	−1,430,475	− 39.6
March	2,184,705	12.9	− 373,622	− 17.1
April	1,811,083	10.7	+3,428,890	+189.3
May	5,239,973	31.0	+7,295,186	+139.2
June	12,535,159	74.2	+3,640,665	+ 29.0
July	16,175,824	95.7	+ 720,465	+ 4.5
August	16,896,289	100.0	− 560,920	− 3.3
September	16,335,369	96.7	− 549,432	− 3.4
October	15,785,937	93.4	− 1,363	− 0.009
November	15,784,574	93.4	+ 145,177	+ 0.9
December	15,929,751	94.3	−3,129,653	− 19.6

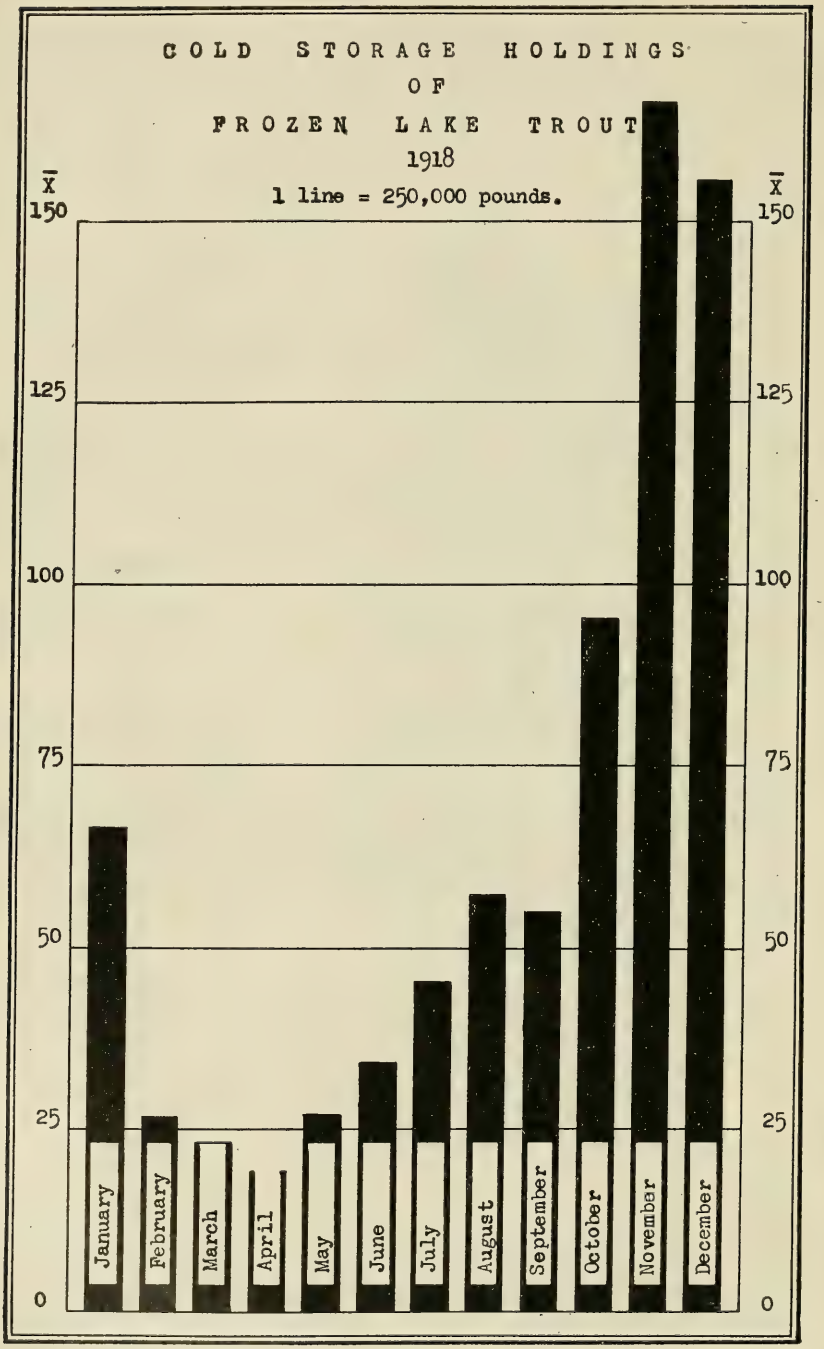
COLD STORAGE HOLDINGS
OF
FROZEN LAKE TROUT
1918
1 line = 250,000 pounds.
X̄
150
125
100
75
50
25
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 23.

TABLE 35.—*Monthly cold storage holdings of frozen herring during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	106	5,891,359	85	6,749,138	5,035,037	− 25.4
February	111	3,615,180	87	3,293,540	2,357,386	− 28.4
March	114	2,184,705	91	1,892,239	1,771,838	− 6.4
April	108	1,811,083	92	1,160,329	1,450,814	+ 25.0
May	91	5,239,973	74	3,689,386	4,987,126	+ 35.2
June	81	12,535,159	63	5,901,584	12,196,421	+106.7
July	86	16,175,824	69	6,629,423	15,660,226	+136.2
August	84	16,896,289	68	6,231,331	15,383,918	+146.9
September	76	16,335,369	61	5,955,136	14,082,451	+136.5
October	78	15,785,937	72	7,456,256	15,582,462	+109.0
November	84	15,784,574	81	7,427,127	16,063,135	+116.3
December	89	15,929,751	86	7,848,532	15,288,351	+ 94.8

LAKE TROUT.

"The trout is found in the Great Lakes and in the smaller lakes of the Northern States. In different localities the individuals vary greatly in color, size and shape, and are known by the local names 'salmon trout,' 'namaycush,' 'togue,' 'tuladi,' 'Mackinaw trout,' 'lake salmon,' 'black trout,' 'reef trout,' 'longe,' etc. The 'siscowet' is another variety of this species."

On January 15, 1918, 666,706 pounds of the lake trout still remained in cold storage from the catch of the previous season. The stocks declined until April 15, when less than 200,000 pounds remained. The holdings then increased monthly, except for a slight decrease between August 15 and September 15, until November 15, when reports showed 1,660,112 pounds. This was 28.3 per cent more than was stored on the same date in 1917.

TABLE 36.—*Monthly cold storage holdings of frozen lake trout during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	666,706	40.2	−396,327	−59.4
February	270,379	16.3	− 38,705	−14.3
March	231,674	14.0	− 35,196	−15.2
April	196,478	11.8	+ 72,907	+37.1
May	269,385	16.2	+ 73,034	+27.1
June	342,419	20.6	+109,618	+32.0
July	452,037	27.2	+121,078	+26.8
August	573,115	34.5	− 22,227	− 3.9
September	550,888	33.2	+400,758	+72.7
October	951,646	57.3	+708,466	+74.4
November	1,660,112	100.0	−108,847	− 6.6
December	1,551,265	93.4	−350,485	−22.6

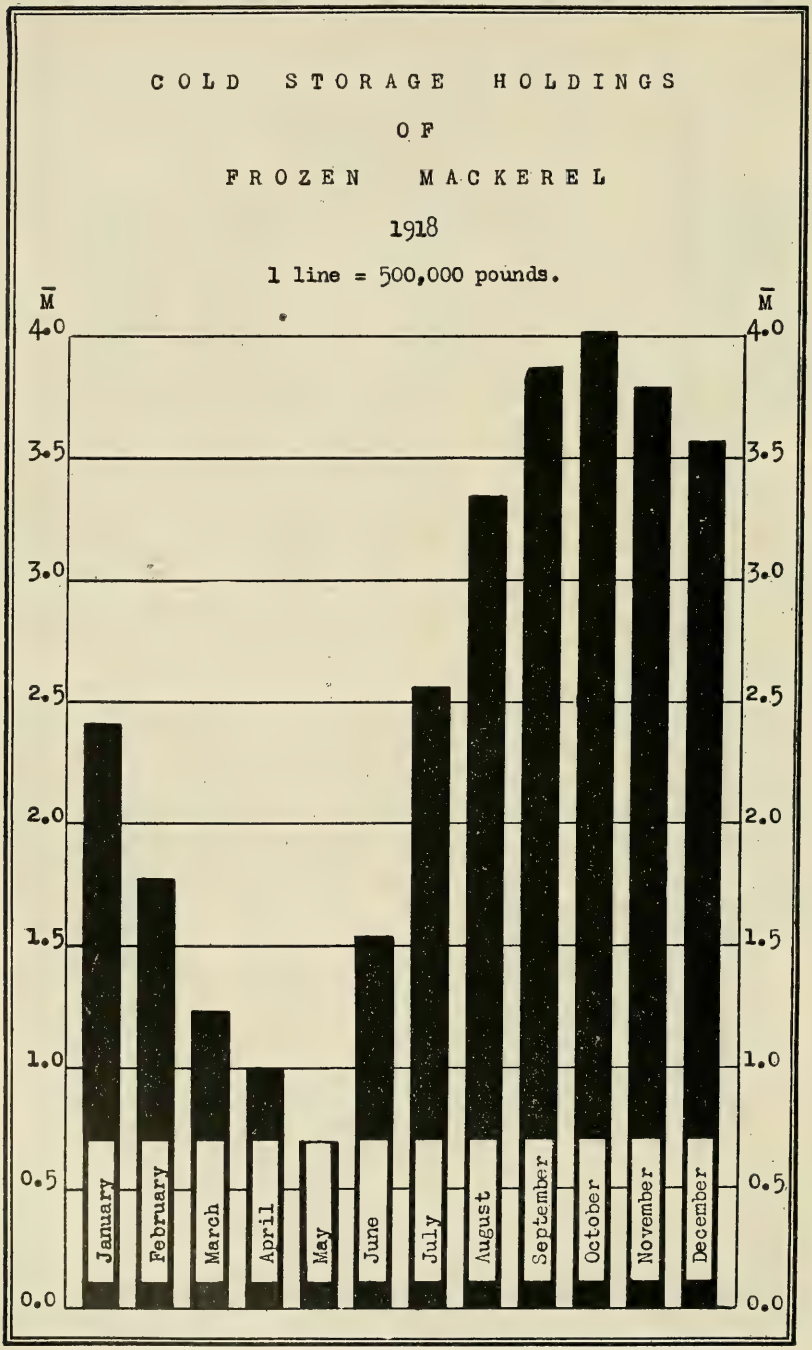
COLD STORAGE HOLDINGS
OF
FROZEN MACKEREL
1918
1 line = 500,000 pounds.
M
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 24.

TABLE 37.—*Monthly cold storage holdings of frozen lake trout during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	59	666,706	48	392,008	275,674	− 29.7
February	65	270,379	49	152,750	106,707	− 30.1
March	68	231,674	53	80,276	135,852	+ 69.2
April	65	196,478	53	43,403	95,662	+120.4
May	44	269,385	35	120,386	153,511	+ 27.5
June	44	342,419	36	138,804	182,030	+ 31.1
July	51	452,037	43	195,618	255,119	+ 30.4
August	54	573,115	46	218,329	288,822	+ 32.3
September	48	550,888	39	202,220	233,170	+ 15.3
October	52	951,646	47	482,396	937,249	+ 94.3
November	59	1,660,112	58	1,291,734	1,657,789	+ 28.3
December	62	1,551,265	61	1,049,841	1,551,265	+ 47.8

MACKEREL.

The mackerel is "a very important food fish found in the North Atlantic south of Cape Hatteras. They range from 9 to 18 inches in length and one-half to 3 pounds in weight. They are sold fresh, salted, pickled, and canned and are sometimes used for bait." Spanish mackerel are not included in this classification in the report of the Bureau of Markets.

The stocks of frozen mackerel in cold storage on January 15 amounted to 2,414,186 pounds. The holdings decreased until May 15, when less than 700,000 pounds were held. The largest decrease occurred from January 15 to February 15 and amounted to 635,691 pounds. The stocks increased from May 15 to October 15, the greatest increase occurring between June 15 and July 15, during which time more than 1,000,000 pounds were frozen. On October 15 the stocks amounted to 4,114,564 pounds, a decrease of almost 2 per cent from the holdings of October 15, 1917. The stocks decreased more than 500,000 pounds from October 15 to December 15, but increased slightly after that date.

TABLE 38.—*Monthly cold storage holdings of frozen mackerel during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	2,414,186	58.7	− 635,691	− 26.3
February	1,778,495	43.2	− 548,045	− 30.8
March	1,230,450	29.9	− 228,713	− 18.6
April	1,001,737	24.3	− 305,083	− 30.5
May	696,654	16.9	+ 835,568	+119.9
June	1,532,222	37.2	+1,026,433	+ 67.0
July	2,558,655	62.2	+ 784,238	+ 30.7
August	3,342,893	81.2	+ 540,308	+ 16.2
September	3,883,201	94.4	+ 231,363	+ 6.0
October	4,114,564	100.0	− 329,868	− 8.0
November	3,784,696	92.0	− 215,320	− 5.7
December	3,569,376	86.7	+ 305,217	+ 8.6

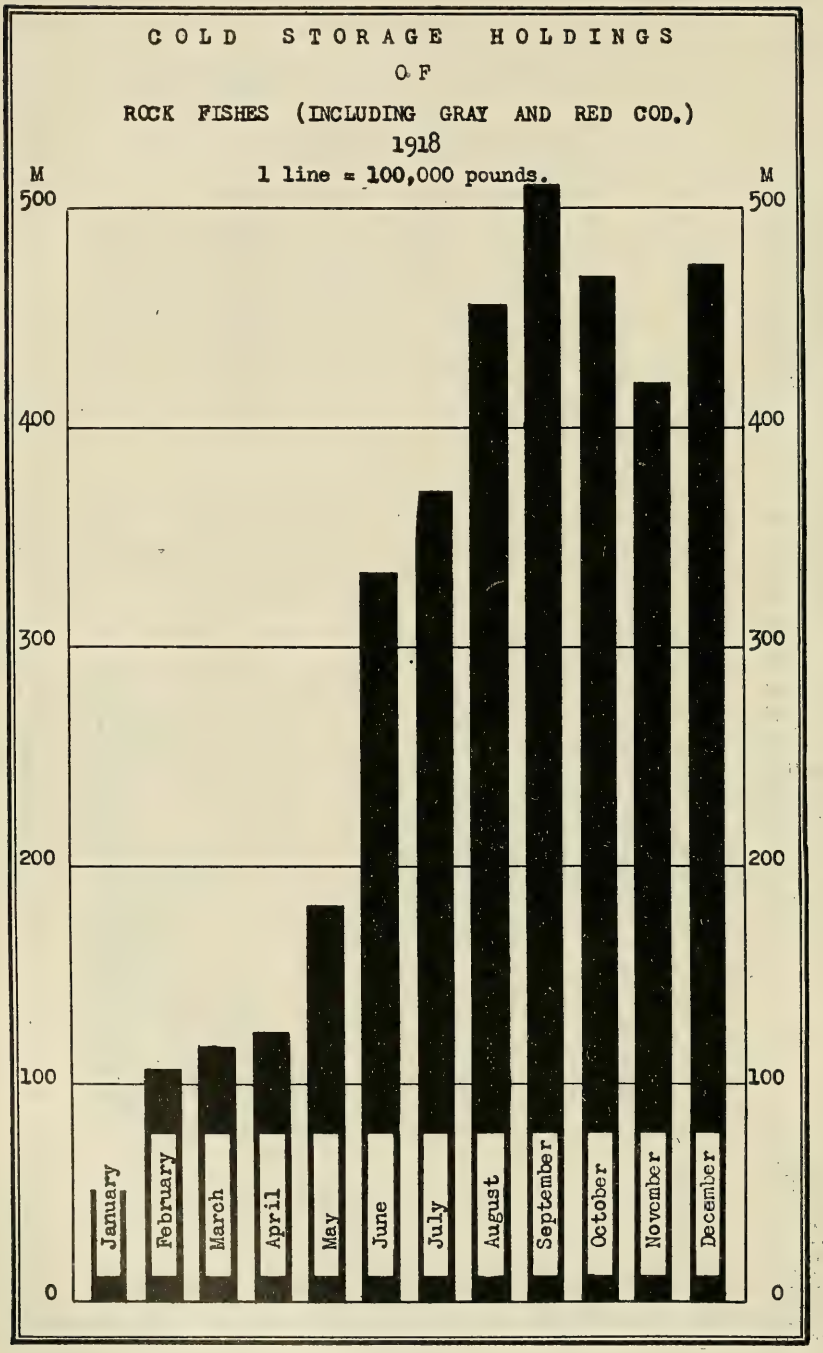
COLD STORAGE HOLDINGS
OF
ROCK FISHES (INCLUDING GRAY AND RED COD.)
1918
1 line = 100,000 pounds.
M
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 25.

TABLE 39.—*Monthly cold storage holdings of frozen mackerel during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	84	2,414,186	69	1,653,800	1,825,314	+10.4
February	97	1,778,495	76	937,092	1,171,208	+25.0
March	97	1,230,450	78	817,218	1,022,538	+25.1
April	96	1,001,737	80	714,253	982,230	+37.5
May	73	696,654	58	708,192	598,132	−15.5
June	74	1,532,222	61	1,066,870	1,285,367	+20.5
July	79	2,558,655	66	1,583,291	2,090,355	+32.0
August	82	3,342,893	68	2,110,405	2,652,354	+25.7
September	83	3,883,201	67	2,340,776	2,986,302	+27.6
October	89	4,114,564	79	3,657,805	3,595,812	− 1.7
November	95	3,784,696	88	4,036,607	3,631,292	−10.0
December	88	3,569,376	85	3,102,732	3,568,216	+15.0

ROCK FISHES.

"These fish are caught in enormous quantities on the Pacific Coast, especially from Santa Barbara to San Francisco. There are a large number of species, known to the fishermen as 'priest fish,' 'rock cod,' and 'rockfish' with many qualifying prefixes, as 'black,' 'black-banded,' 'brown,' 'grass,' 'green,' 'orange,' 'red,' 'yellow,' 'yellow-backed,' 'yellow-tail,' etc.; also called 'garrupa,' 'grouper,' 'scorpene,' 'sculpin,' 'scorpion,' 'treefish,' 'flyfish,' 'corsair,' 'Spanish flag,' 'reina,' 'black-bass,' 'jack,' 'tomcod,' 'boccaccio,' etc. They average 15 inches in length and 2 to 3 pounds in weight, but some reach a length of 3 feet and a weight of 12 pounds. They are caught in seines and with hook and line."

On January 15, 1918, there were only 51,480 pounds of rock fishes in cold storage. The stocks increased each month until September 15, when the reports showed holdings of 510,477 pounds. This stock was 105.5 per cent greater than the stock on hand September 15, 1917.

TABLE 40.—*Monthly cold storage holdings of frozen rock fishes during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	51,480	10.1	+ 56,070	+108.9
February	107,550	21.1	+ 9,737	+ 9.1
March	117,287	23.0	+ 6,467	+ 5.5
April	123,754	24.2	+ 58,898	+ 47.6
May	182,652	35.8	+150,396	+ 82.3
June	333,048	65.2	+ 38,211	+ 11.5
July	371,259	72.7	+ 84,302	+ 22.7
August	455,561	89.2	+ 54,916	+ 12.1
September	510,477	100.0	− 42,030	− 8.2
October	468,447	91.8	− 47,860	− 10.2
November	420,587	82.4	+ 52,613	+ 12.5
December	473,200	92.7	−161,212	− 34.1

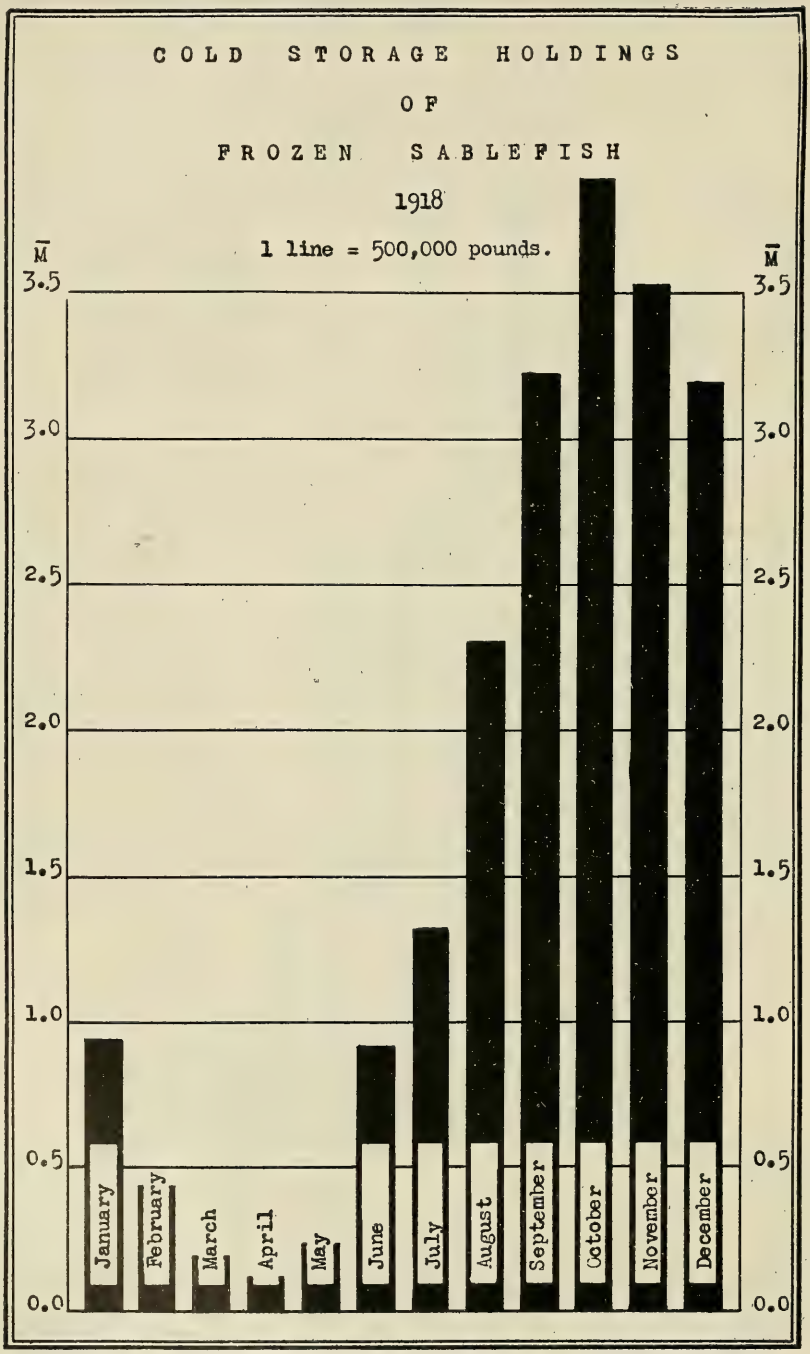
COLD STORAGE HOLDINGS
OF
FROZEN SABLEFISH
1918
1 line = 500,000 pounds.
M
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 26.

TABLE 41.—*Monthly cold storage holdings of frozen rock fishes during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	15	51,480	14	392	30,215	+7607.9
February	24	107,550	18	530	32,539	+6039.4
March	24	117,287	20	14,826	70,928	+ 378.4
April	24	123,754	20	31,724	105,777	+ 233.4
May	23	182,652	20	84,091	169,229	+ 101.2
June	20	333,048	17	103,930	274,903	+ 164.5
July	22	371,259	18	203,887	331,848	+ 62.8
August	25	455,561	21	169,194	425,468	+ 151.5
September	20	510,477	14	155,793	320,168	+ 105.5
October	17	468,447	15	117,872	454,511	+ 285.6
November	19	420,587	17	131,289	407,291	+ 210.2
December	23	473,200	21	130,014	468,995	+ 260.7

SABLEFISH (BLACK COD).

From January 15 to April 15, 1918, the holdings of frozen sablefish decreased from 941,658 pounds to 122,425 pounds. They then increased monthly until October 15, when the holdings were 3,878,725 pounds. This amount was 180.6 per cent greater than the stocks held on October 15, 1917. By December 15 the stocks had been reduced 694,142 pounds.

TABLE 42.—*Monthly cold storage holdings of frozen sablefish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	941,658	24.3	−511,210	− 54.3
February	430,448	11.1	−238,424	− 55.4
March	192,024	5.0	− 69,599	− 36.2
April	122,425	3.2	+111,669	+ 91.2
May	234,094	6.0	+681,855	+291.3
June	915,949	23.6	+402,461	+ 43.9
July	1,318,410	34.0	+981,451	+ 74.4
August	2,299,861	59.3	+915,240	+ 39.8
September	3,215,101	82.9	+663,624	+ 20.6
October	3,878,725	100.0	−360,194	− 9.3
November	3,518,531	90.7	−333,948	9.5
December	3,184,583	82.1	−373,644	− 11.7

TABLE 43.—*Monthly cold storage holdings of frozen sablefish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	46	941,658	41	542,353	837,788	+ 54.5
February	56	430,448	45	341,991	367,211	+ 7.4
March	57	192,024	47	95,573	176,983	+ 85.2
April	56	122,425	47	100,131	113,872	+ 13.7
May	43	234,094	36	121,842	225,955	+ 85.4
June	37	915,949	30	657,145	905,993	+ 37.9
July	40	1,318,410	34	1,154,987	914,917	− 20.8
August	41	2,299,861	34	1,646,857	1,643,295	− 0.2
September	37	3,215,101	28	1,668,238	2,319,802	+ 39.1
October	40	3,878,725	36	1,195,581	3,354,524	+180.6
November	44	3,518,531	42	1,456,023	3,345,769	+129.8
December	46	3,184,583	46	1,830,063	3,184,583	+ 74.0

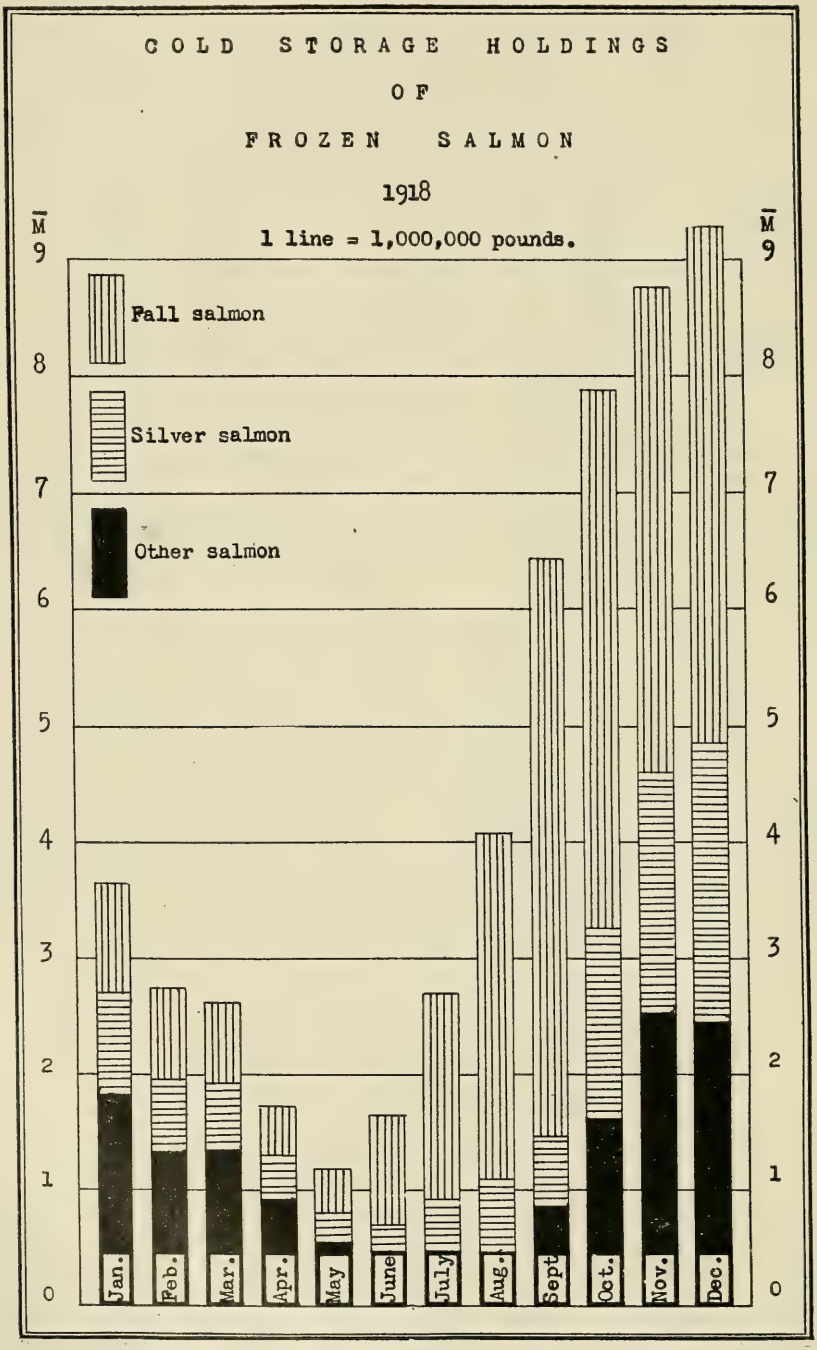
COLD STORAGE HOLDINGS
OF
FROZEN SALMON
1918
1 line = 1,000,000 pounds.
M
9
8
7
6
5
4
3
2
1
0
Fall salmon
Silver salmon
Other salmon
Jan.
Feb.
Mar.
Apr.
May
June
July
Aug.
Sept
Oct.
Nov.
Dec.

FIG. 27.

SALMON.

The bureau's reports show separate holdings for "fall salmon" and "silver salmon." All other salmon, including sockeye, chinook, steelhead trout, etc., are grouped together.

The largest stocks of fall salmon were held in cold storage on November 15 and amounted to 2,515,056 pounds, a decrease of almost 10 per cent from the stocks held in 1917. The stocks reached their lowest point on August 15, when the reports showed 452,113 pounds.

On December 15 the reports showed holdings of 2,401,313 pounds of silver salmon. This was more than double the stocks held on the same date in 1917. The lowest holdings were reported on June 15 and amounted to 238,965 pounds.

The stocks of miscellaneous salmon on January 15 amounted to 952,045 pounds. The holdings decreased to 436,528 pounds on April 15, then increased until September 15. The stocks on that date were 4,983,197 pounds, an increase of 104.5 per cent over those of September 15, 1917.

TABLE 44.—*Monthly cold storage holdings of frozen fall salmon during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	1,825,755	72.6	−484,748	−26.6
February	1,341,007	53.3	− 3,327	− 0.2
March	1,337,680	53.2	−425,699	−31.8
April	911,981	36.3	−369,353	−40.5
May	542,628	21.6	− 74,321	−13.7
June	468,307	18.6	+ 4,295	+ 0.9
July	472,602	18.8	− 20,489	− 4.3
August	452,113	18.0	+396,628	+87.7
September	848,741	33.7	+766,212	+90.3
October	1,614,953	64.2	+900,103	+55.7
November	2,515,056	100.0	− 70,168	− 2.8
December	2,444,888	97.2	−125,844	− 5.1

TABLE 45.—*Monthly cold storage holdings of frozen fall salmon during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	86	1,825,755	71	2,086,737	1,448,673	−30.6
February	99	1,341,007	80	792,460	826,926	+ 4.3
March	98	1,337,680	78	1,058,601	922,609	−12.8
April	97	911,981	78	492,838	593,823	+20.5
May	76	542,628	61	370,028	307,838	−16.8
June	64	468,307	47	257,784	321,715	+24.8
July	66	472,602	51	255,983	322,109	+25.8
August	67	452,113	52	356,215	331,331	− 7.0
September	52	848,741	40	548,058	699,904	+27.7
October	63	1,614,953	55	846.570	1,399,857	+65.4
November	68	2,515,056	62	2,554,937	2,309,698	− 9.6
December	80	2,444,888	77	1,971,380	2,174,964	+10.3

TABLE 46.—*Monthly cold storage holdings of frozen silver salmon during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	888,497	37.0	− 268,387	− 30.2
February	620,110	25.8	− 46,130	− 7.4
March	573,980	23.9	− 191,411	− 33.3
April	382,569	15.9	− 126,804	− 33.1
May	255,765	10.7	− 16,800	− 6.6
June	238,965	10.0	+ 197,582	+ 82.7
July	436,547	18.2	+ 205,441	+ 47.1
August	641,988	26.7	− 29,374	− 4.6
September	612,614	25.5	+1,020,828	+166.6
October	1,633,442	68.0	+ 442,149	+ 27.1
November	2,075,591	86.4	+ 325,722	+ 15.7
December	2,401,313	100.0	− 23,893	− 1.0

TABLE 47.—*Monthly cold storage holdings of frozen silver salmon during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	63	888,497	54	1,112,889	779,445	− 30.0
February	71	620,110	60	362,952	511,563	+ 40.9
March	72	573,980	64	577,462	508,760	− 11.9
April	69	382,569	62	459,974	342,175	− 25.6
May	49	255,765	42	261,147	232,974	− 10.8
June	39	238,965	33	316,528	218,802	− 30.9
July	45	436,547	40	296,091	306,145	+ 3.4
August	46	641,988	40	316,993	605,418	+ 91.0
September	41	612,614	36	625,718	519,922	− 16.9
October	44	1,633,442	39	1,173,555	1,422,110	+ 21.2
November	55	2,075,591	48	1,024,121	1,724,362	+ 68.4
December	67	2,401,313	65	1,118,341	2,323,621	+107.8

TABLE 48.—*Monthly cold storage holdings of miscellaneous frozen salmon during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	952,045	19.1	− 164,380	− 17.3
February	787,665	15.8	− 93,873	− 11.9
March	693,792	13.9	− 257,264	− 37.1
April	436,528	8.8	− 45,593	− 10.4
May	390,935	7.8	+ 557,340	+142.6
June	948,275	19.0	+ 834,469	+ 88.0
July	1,782,744	35.8	+1,187,323	+ 66.6
August	2,970,067	59.6	+2,013,130	+ 67.8
September	4,983,197	100.0	− 356,194	− 7.1
October	4,627,003	92.9	− 469,993	− 10.2
November	4,157,010	83.4	+ 292,279	+ 7.0
December	4,449,289	89.3	− 197,406	− 4.4

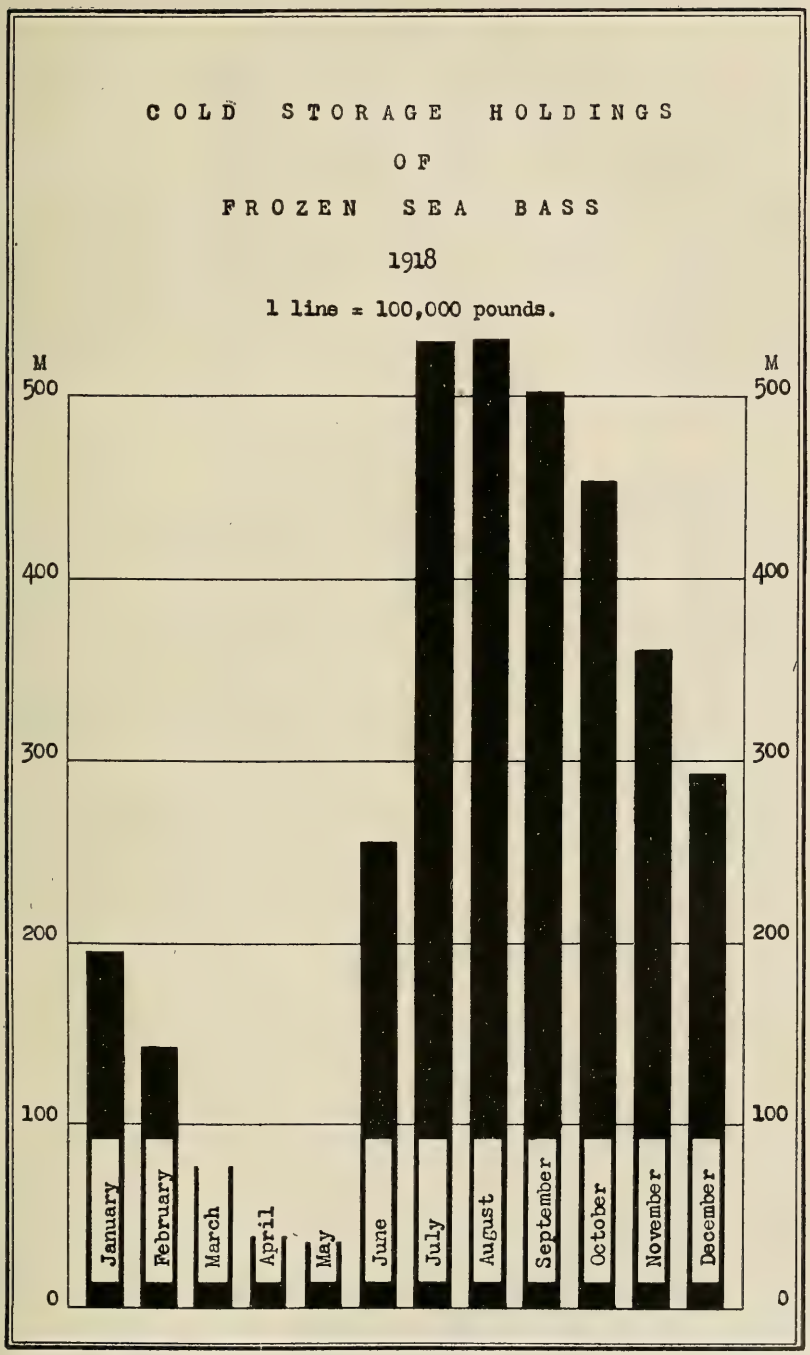
COLD STORAGE HOLDINGS
OF
FROZEN SEA BASS
1918
1 line = 100,000 pounds.
M
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 28.

TABLE 49.—*Monthly cold storage holdings of miscellaneous frozen salmon during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	65	952,045	53	2,553,580	2,137,615	− 16.3
February	67	787,665	56	976,664	740,951	− 24.1
March	66	693,792	55	525,457	638,478	+ 21.5
April	66	436,528	56	388,597	421,704	+ 8.5
May	55	390,935	46	362,817	279,447	− 23.0
June	44	948,275	36	461,160	893,342	+ 93.7
July	53	1,782,744	44	1,194,129	1,602,545	+ 34.2
August	55	2,970,067	46	1,320,706	2,688,985	+103.6
September	54	4,983,197	42	1,608,215	3,289,317	+104.5
October	52	4,627,003	46	1,687,833	3,897,882	+130.9
November	55	4,157,010	54	1,730,685	4,777,810	+176.1
December	60	4,449,289	59	1,265,322	4,449,289	+251.6

SEA BASS.

The sea bass is "a food fish found from Vineyard Sound to the eastern part of the Gulf of Mexico. It is known south of Cape Hatteras as the 'blackfish'; in the Middle States as 'black Will,' 'black Harry,' and 'hannahills'; about New Bedford and Newport as 'bluefish,' and at New Bedford also as 'rock bass.' The average length in New England is about 15 inches, average weight one and one-half pounds. In the South they are much smaller, averaging about three-fourths of a pound in weight. They are caught with hand lines and in pounds and traps. The white sea bass is found on the Pacific Coast from Cape Mendocino to San Diego. It is an important food fish, and averages 15 pounds in weight. The redfish is called 'sea bass' in the Carolinas, Florida, and the Gulf."

The largest stocks of sea bass reported during the year were held on August 15 and amounted to 532,725 pounds. This was 20 per cent less than was held on August 15, 1917. The smallest quantity, 35,845 pounds, was reported on May 15. The greatest increase occurred from May 15 to July 15, approximately 500,000 pounds of the stocks of the season being frozen at that time. The holdings decreased during the remainder of the year and on December 15 amounted to 293,248 pounds.

TABLE 50.—*Monthly cold storage holdings of frozen sea bass during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	196,627	36.9	− 53,386	− 27.2
February	143,241	26.9	− 66,292	− 46.3
March	76,949	14.4	− 36,473	− 47.4
April	40,476	7.6	− 4,631	− 11.4
May	35,845	6.7	+221,602	+618.2
June	257,447	48.3	+273,012	+106.0
July	530,459	99.6	+ 2,266	+ 0.4
August	532,725	100.0	− 30,748	− 5.8
September	501,977	94.2	− 47,691	− 9.5
October	454,286	85.3	− 93,410	− 20.6
November	360,876	67.7	− 67,628	− 18.7
December	293,248	55.0	− 52,877	− 18.0

TABLE 51.—*Monthly cold storage holdings of frozen sea bass during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	39	196,627	30	339,383	116,268	−65.7
February	42	143,241	31	124,772	53,737	−56.9
March	43	76,949	36	146,321	57,543	−60.7
April	39	40,476	34	80,534	37,051	−54.0
May	31	35,845	23	48,050	32,648	−32.1
June	29	257,447	22	193,387	200,855	+ 3.9
July	34	530,459	26	407,234	387,910	− 4.7
August	36	532,725	29	498,664	398,998	−20.0
September	35	501,977	28	409,755	368,979	−10.0
October	36	454,286	34	395,925	414,959	+ 4.8
November	37	360,876	37	482,872	360,876	−25.3
December	38	293,248	38	402,251	293,248	−27.1

SHAD.

The shad is "a very important food fish found on all the coasts and in some inland waters; the great fisheries are in the rivers of the Atlantic slope. It is called 'white shad,' in distinction from other 'shad.' The average weight is about 4 pounds, average length about 2 feet. It is caught in nets, seines and weirs, and is sold fresh, cured, and pickled."

On January 15, 1918, reports showed stocks of 564,739 pounds of frozen shad. The holdings decreased to 289,776 pounds on April 15. During the period from April 15 to June 15 the holdings were increased by 567,556 pounds. This was 137.6 per cent more than was stored on June 15, 1917. The reports of the Bureau of Markets also show stocks of shad roe. The report of June 15 showed more than 64,000 pounds in cold storage.

TABLE 52.—*Monthly cold storage holdings of frozen shad during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	564,739	65.9	−245,450	− 43.5
February	319,289	37.2	− 15,968	− 5.0
March	303,321	35.4	− 13,545	− 4.5
April	289,776	33.8	+ 88,557	+ 30.6
May	378,333	44.1	+478,999	+126.6
June	857,332	100.0	− 76,763	− 9.0
July	780,569	91.0	− 9,121	− 1.2
August	771,448	90.0	− 9,018	− 1.2
September	762,430	88.9	− 2,387	− 0.3
October	760,043	88.7	− 36,857	− 4.8
November	723,186	84.4	− 89,470	− 12.4
December	633,716	73.9	−182,402	− 28.8

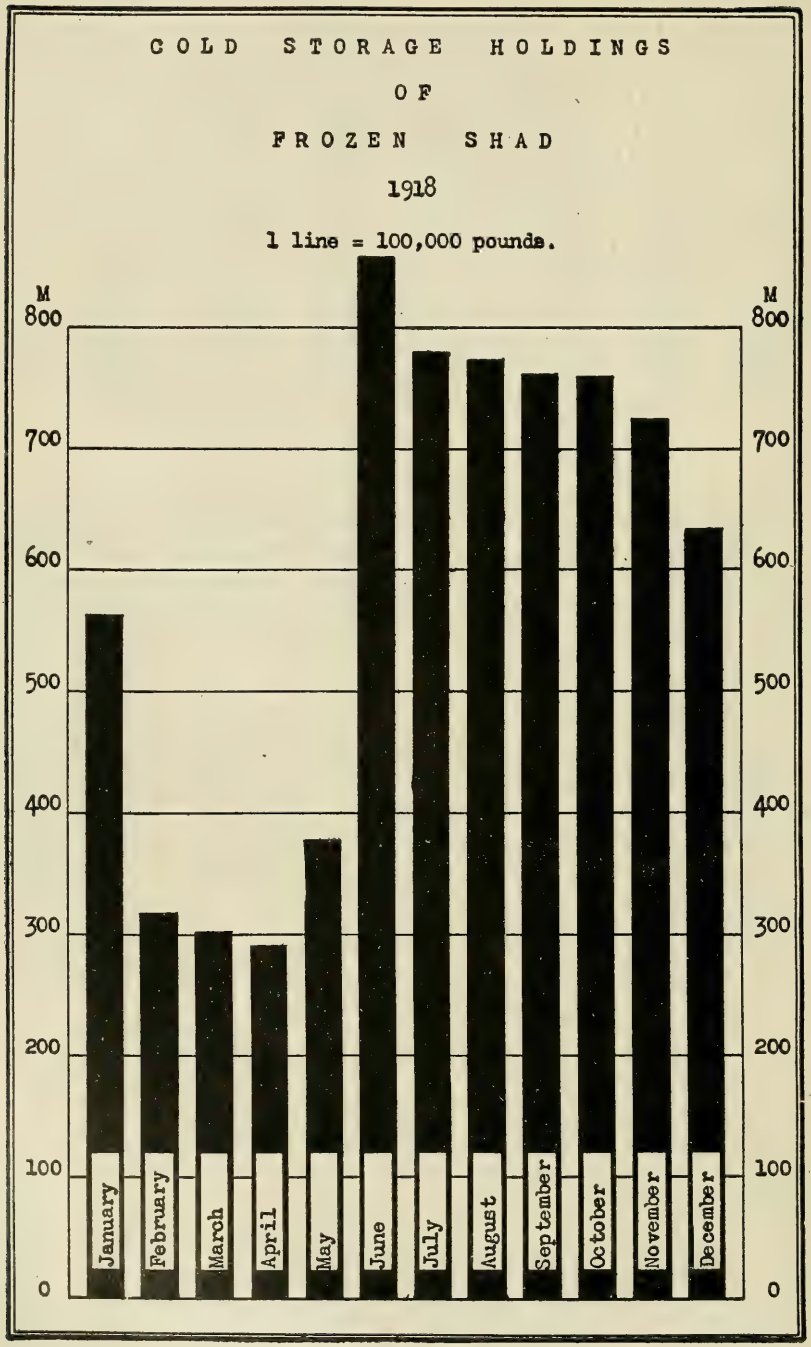
COLD STORAGE HOLDINGS
OF
FROZEN SHAD
1918
1 line = 100,000 pounds.
M
800
700
600
500
400
300
200
100
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 29.

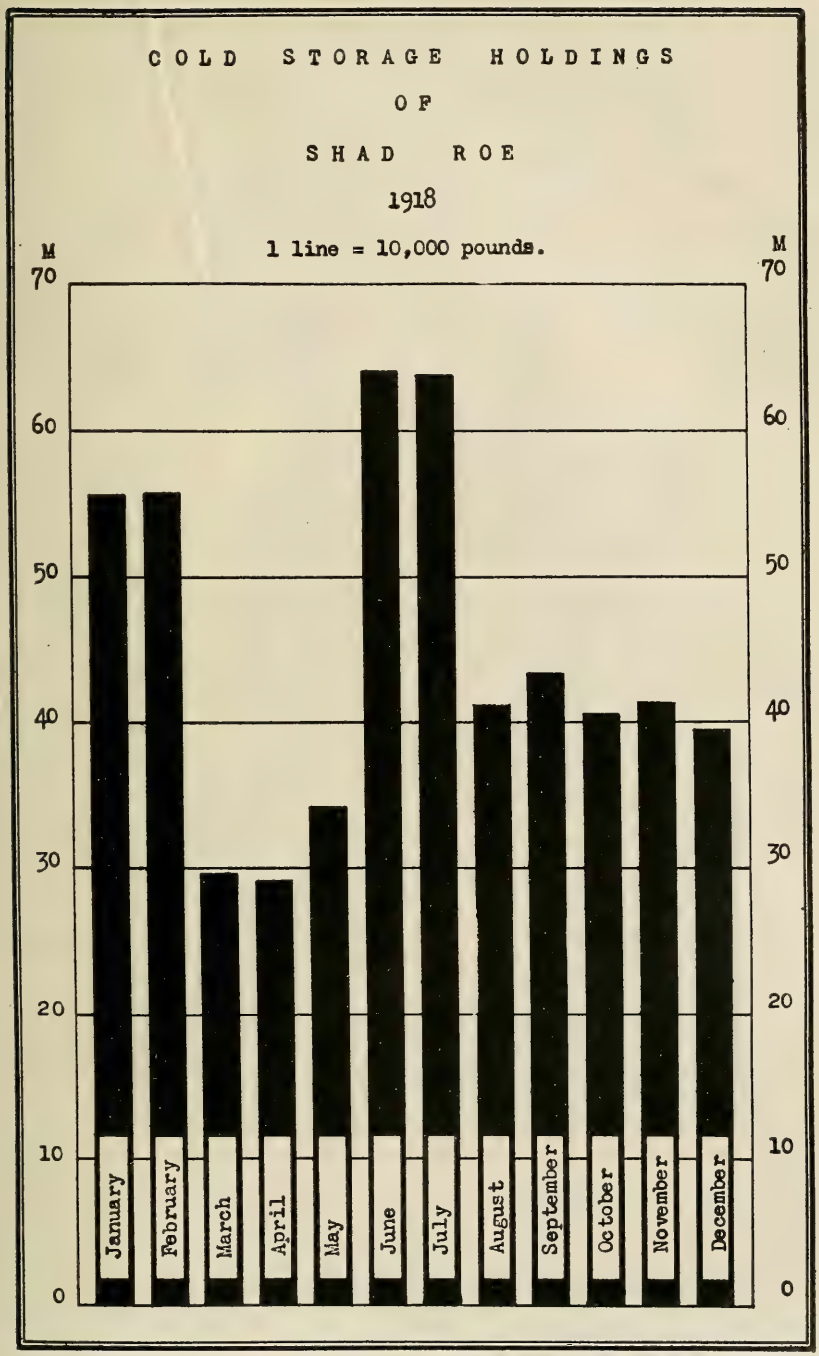
COLD STORAGE HOLDINGS
OF
SHAD ROE
1918
1 line = 10,000 pounds.
M
70
60
50
40
30
20
10
0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 30.

TABLE 53.—*Monthly cold storage holdings of frozen shad during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	63	564,739	47	329,971	309,713	− 6.1
February	68	319,289	51	91,584	95,247	+ 4.0
March	67	303,321	51	134,315	193,293	+ 43.9
April	67	289,776	51	112,455	172,569	+ 53.5
May	54	378,333	42	199,170	223,921	+ 12.4
June	59	857,332	44	389,758	926,085	+137.6
July	65	780,569	51	345,002	636,580	+ 84.5
August	70	771,448	56	391,435	567,958	+ 45.1
September	64	762,430	50	362,240	559,511	+ 54.5
October	70	760,043	59	611,133	688,588	+ 12.7
November	69	723,186	62	579,491	701,564	+ 21.1
December	62	633,716	57	627,919	624,015	− 0.6

TABLE 54.—*Monthly cold storage holdings of frozen shad roe during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	55,124	86.1	+ 1,381	+ 2.5
February	56,505	88.2	−27,050	−47.9
March	29,455	46.0	− 322	− 1.1
April	29,133	45.5	+ 5,254	+18.0
May	34,387	53.7	+29,662	+86.3
June	64,049	100.0	− 371	− 0.6
July	63,678	99.4	−22,554	−35.4
August	41,124	64.2	+ 2,194	+ 5.3
September	43,318	67.6	− 2,690	− 6.2
October	40,628	63.4	+ 781	+ 1.9
November	41,409	64.7	− 1,655	− 4.0
December	39,754	62.1	−11,912	−30.0

TABLE 55.—*Monthly cold storage holdings of frozen shad roe during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	53	55,124	41	29,548	31,016	+ 5.0
February	54	56,505	41	8,540	8,293	− 2.9
March	53	29,455	42	18,190	8,637	− 52.5
April	51	29,133	40	5,454	15,136	+177.5
May	43	34,387	32	8,247	12,683	+ 53.8
June	44	64,049	32	12,410	23,077	+ 86.0
July	45	63,678	33	11,076	26.775	+141.7
August	42	41,124	31	12,283	26,488	+115.6
September	37	43,318	27	12,706	23,958	+ 88.6
October	43	40,628	37	44,886	35,235	− 21.5
November	48	41,409	45	56,209	41,319	− 26.5
December	45	39,754	43	64,897	39,738	− 38.8

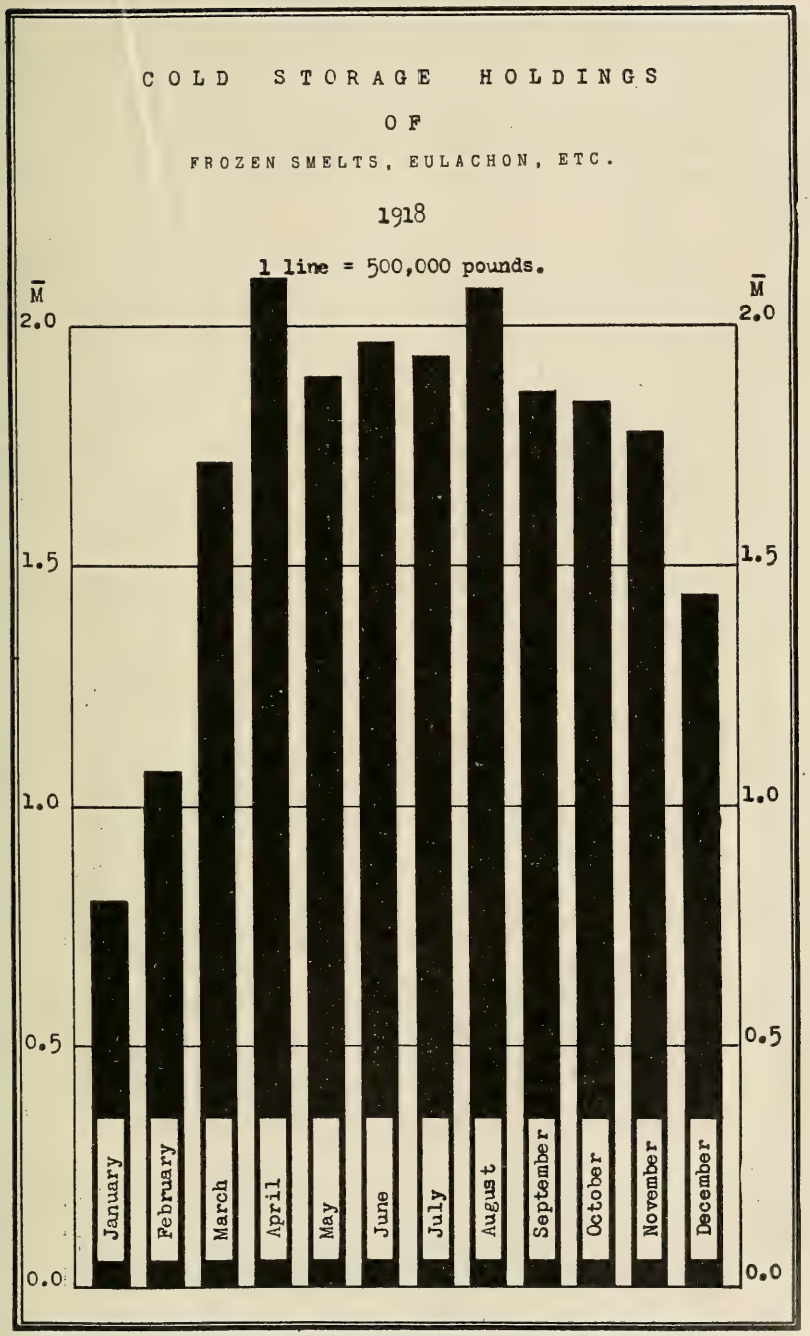
COLD STORAGE HOLDINGS
OF
FROZEN SMELTS, EULACHON, ETC.
1918
1 line = 500,000 pounds.
M
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 31.

SMELTS, EULACHON, ETC.

The smelt is "a very choice food fish found on the Atlantic Coast from Virginia to the St. Lawrence and landlocked in many New England lakes. Also called 'American smelt' and 'frostfish.' When sent to market unfrozen they are known as 'green' smelts. The average length is 8 to 10 inches. The Pacific smelt is found from San Francisco to Alaska. The surf smelt is found from Monterey to Alaska."

The Eulachon is "a small fish common in the rivers and coast of the North Pacific. The Indian name 'oolican' (hoolakins) is often used. The trade name is 'candlefish.' On the Columbia River the name 'smelt' is used. The length averages a little less than 1 foot. It is an excellent food fish, and is also of importance for the oil it yields, which is used as substitute for cod liver oil."

On January 15 the stocks of frozen smelts amounted to a little more than 800,000 pounds. They increased until April 15, when 2,098,022 pounds were reported. The stocks reported for May, June, and July 15 were somewhat less but increased from July 15 to August 15. A decrease then occurred monthly until the fifteenth of December. The stocks on April 15 were 51.2 per cent greater than those on April 15, 1917.

TABLE 56.—*Monthly cold storage holdings of frozen smelts during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	807,025	38.5	+263,925	+32.7
February	1,070,950	51.0	+646,839	+60.4
March	1,717,789	81.9	+380,233	+22.1
April	2,098,022	100.0	−209,160	−10.0
May	1,888,862	90.0	+ 74,784	+ 4.0
June	1,963,646	93.6	− 30,213	− 1.5
July	1,933,433	92.2	+144,426	+ 7.5
August	2,077,859	99.0	−213,745	−10.3
September	1,864,114	88.9	− 23,485	− 1.3
October	1,840,629	87.7	− 65,549	− 3.6
November	1,775,080	84.6	−333,185	−18.8
December	1,441,895	68.7	−210,618	−14.6

TABLE 57.—*Monthly cold storage holdings of frozen smelts during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	67	807,025	56	216,747	509,036	+134.9
February	76	1,070,950	60	358,141	652,535	+ 82.2
March	82	1,717,789	65	876,171	1,359,084	+ 55.1
April	78	2,098,022	63	1,050,508	1,588,602	+ 51.2
May	61	1,888,862	49	986,587	1,327,593	+ 34.6
June	59	1,963,646	46	925,268	1,512,595	+ 63.5
July	59	1,933,433	45	794,234	1,191,644	+ 50.0
August	61	2,077,859	48	845,276	1,561,429	+ 84.7
September	54	1,864,114	41	813,272	1,172,183	+ 44.1
October	57	1,840,629	50	1,120,977	1,519,771	+ 35.6
November	60	1,775,080	57	1,222,516	1,689,470	+ 38.2
December	69	1,441,895	67	956,278	1,441,535	+ 50.7

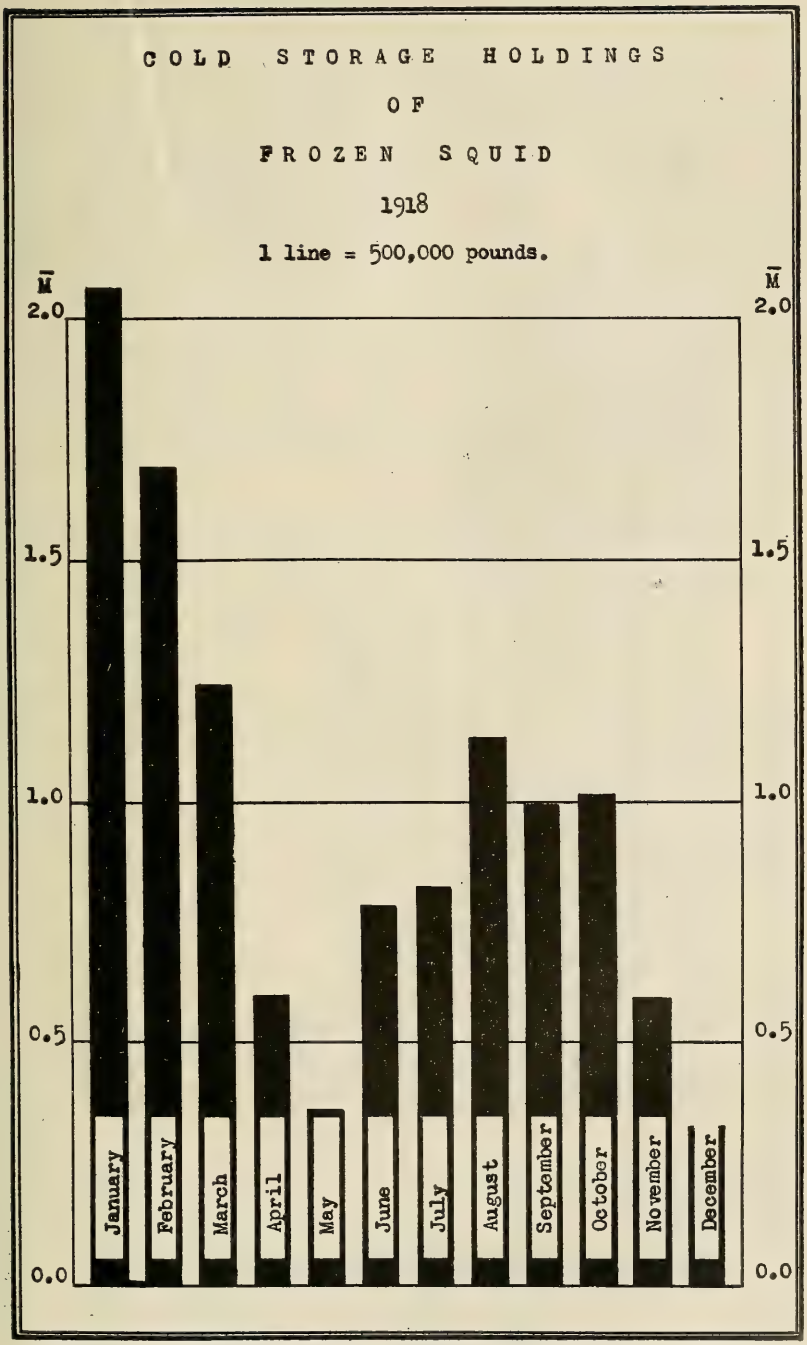
COLD STORAGE HOLDINGS
OF
FROZEN SQUID
1918
1 line = 500,000 pounds.
M
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 32.

SQUID.

In the special report of the Bureau of Census on the Fisheries of the United States the squid is referred to as "cuttle-fish." They are "mollusks found in large numbers all along the coast. The 'common squid,' 'octopus,' 'calamary,' sea arrow,' etc., are different species found in particular localities. They are caught in fish pounds, seines, weirs, and trawls and with fishhooks; large numbers are also taken by driving them on shore by 'torching.' Some are caught with a peculiar arrangement of hooks called a 'squid jig.' Different species vary in length from a few inches to 50 feet. They are important as a bait for many useful fish and as food for man. Oil, 'cuttle bone,' a dentifrice, india ink, etc., are also obtained from them."

The report on January 1, 1918, showed 2,065,680 pounds of squid in cold storage on that date. This was 68.5 per cent more than the quantity held on the same date in 1917. The stocks decreased until May 15, when 362,513 pounds remained in cold storage. An increase occurred on August 15, the stocks then again decreased and on December 15 amounted to 326,247 pounds.

TABLE 58.—*Monthly cold storage holdings of frozen squid during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	2,065,680	100.0	−370,962	− 18.0
February	1,694,718	82.0	−453,271	− 26.7
March	1,241,447	60.1	−641,139	− 51.6
April	600,308	29.1	−237,795	− 39.6
May	362,513	17.5	+424,560	+117.1
June	787,073	38.1	+ 38,213	+ 4.9
July	825,286	40.0	+308,499	+ 37.4
August	1,133,785	54.9	−142,684	− 12.6
September	991,101	48.0	+ 20,655	+ 2.1
October	1,011,756	49.0	−414,092	− 40.9
November	597,664	28.9	−271,417	− 45.4
December	326,247	15.8	− 57,859	− 17.7

TABLE 59.—*Monthly cold storage holdings of frozen squid during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	36	2,065,680	27	1,068,212	1,799,466	+68.5
February	39	1,694,718	29	666,075	1,168,351	+75.4
March	42	1,241,447	31	628,870	1,008,667	+60.4
April	39	600,308	30	347,205	480,362	+38.4
May	30	362,513	22	267,583	273,914	+ 2.4
June	24	787,073	16	1,387,202	534,631	−61.5
July	30	825,286	23	1,501,790	609,461	−59.4
August	27	1,133,785	20	1,901,277	948,434	−50.1
September	25	991,101	19	2,470,616	827,809	−66.5
October	27	1,011,756	26	2,863,006	986,814	−65.5
November	33	597,664	33	3,052,079	597,664	−80.4
December	34	326,247	33	2,434,430	326,247	−86.6

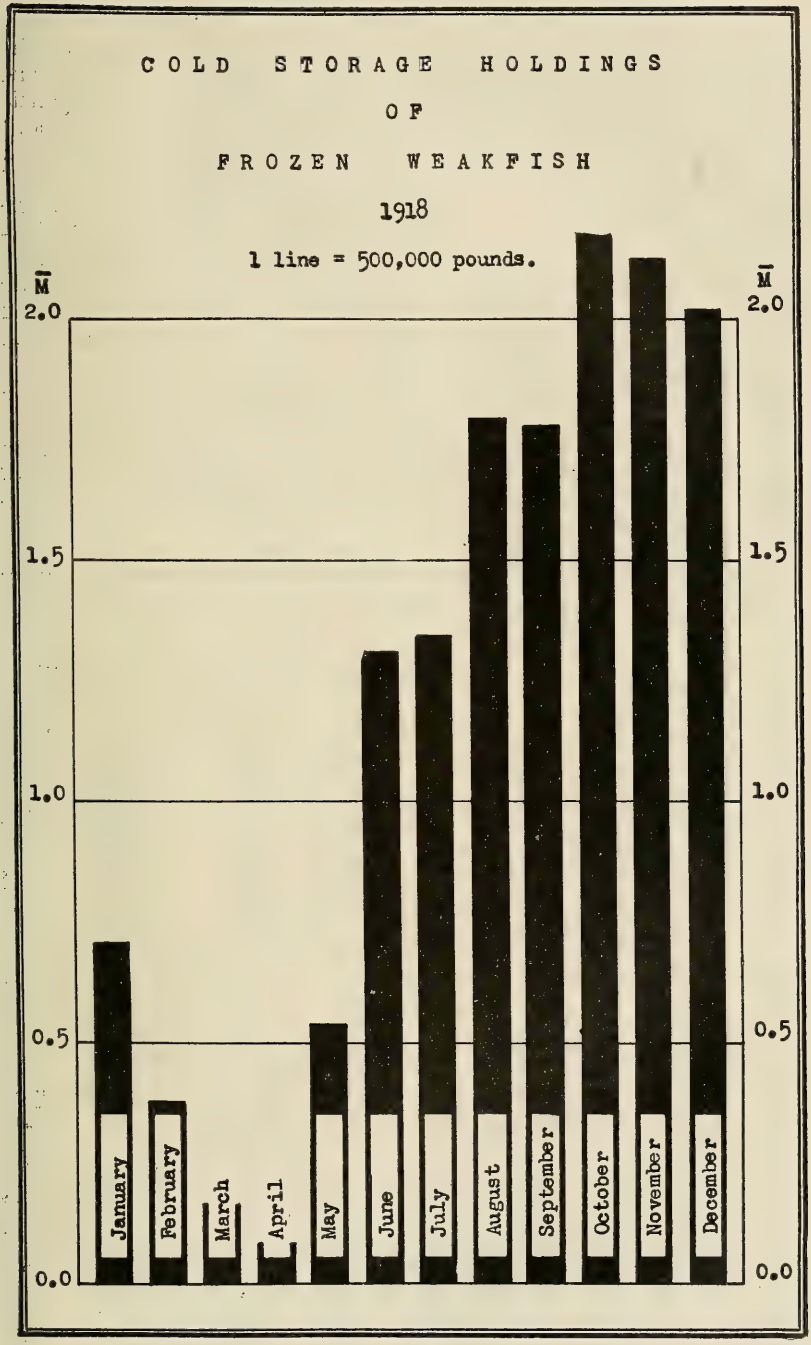
COLD STORAGE HOLDINGS
OF
FROZEN WEAKFISH
1918
1 line = 500,000 pounds.
M
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 33.

WEAKFISH.

The weakfish is given in the special report of the Bureau of the Census on Fisheries of the United States under the name of Squeteague. It is an "excellent food fish found in abundance along the Atlantic Coast from Cape Cod to Florida. It is known as 'drummer' about Cape Cod; 'yellowfin' about Buzzards Bay; 'weakfish' in New York and New Jersey; 'bluefish' in Delaware and Virginia; 'gray trout,' 'sun trout,' 'shad trout,' 'sea trout,' and 'salt water trout' in the Middle and South Atlantic States, and 'squeteague,' 'squit,' 'chickwit,' etc., in various places. It averages about two and one-half pounds in weight, though some individuals attain a weight of 30 pounds. They are caught in seines and gill nets and with hook and line. The spotted squeteague is found from New Jersey to Texas, and is somewhat larger than the preceding."

On January 15, 1918, 712,636 pounds of frozen weakfish remained in cold storage from the previous year. The stocks decreased until April 15, when 85,270 pounds remained. An increase then occurred until October 15 and the reports of that date showed stocks of 2,175,541 pounds. This amount was approximately twice as large as the holdings of the previous year.

TABLE 60.—*Monthly cold storage holdings of frozen weakfish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	712,636	32.8	−335,538	− 47.1
February	377,098	17.3	−208,922	− 55.4
March	168,176	7.7	− 82,906	− 49.3
April	85,270	3.9	+454,486	+533.0
May	539,756	24.8	+769,729	+142.6
June	1,309,485	60.2	+ 35,319	+ 2.7
July	1,344,804	61.8	+449,653	+ 33.4
August	1,794,457	82.5	− 17,672	− 1.0
September	1,776,785	81.7	+398,756	+ 22.4
October	2,175,541	100.0	− 54,098	− 2.5
November	2,121,443	97.5	− 99,343	− 4.7
December	2,022,100	92.9	−507,440	− 25.1

TABLE 61.—*Monthly cold storage holdings of frozen weakfish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	26	712,636	19	443,646	374,545	− 15.6
February	28	377,098	20	88,099	100,347	+ 13.9
March	29	168,176	22	91,493	105,004	+ 14.8
April	27	85,270	21	28,755	65,409	+127.5
May	22	539,756	18	152,402	394,425	+158.8
June	23	1,309,485	19	196,531	962,560	+389.8
July	23	1,344,804	19	228,126	982,969	+330.9
August	26	1,794,457	21	723,097	1,269,802	+ 75.6
September	24	1,776,785	19	546,588	1,228,123	+124.7
October	25	2,175,541	22	930,855	1,846,255	+ 98.3
November	27	2,121,443	25	1,460,003	2,117,273	+ 45.0
December	28	2,022,100	28	1,156,420	2,022,100	+ 74.9

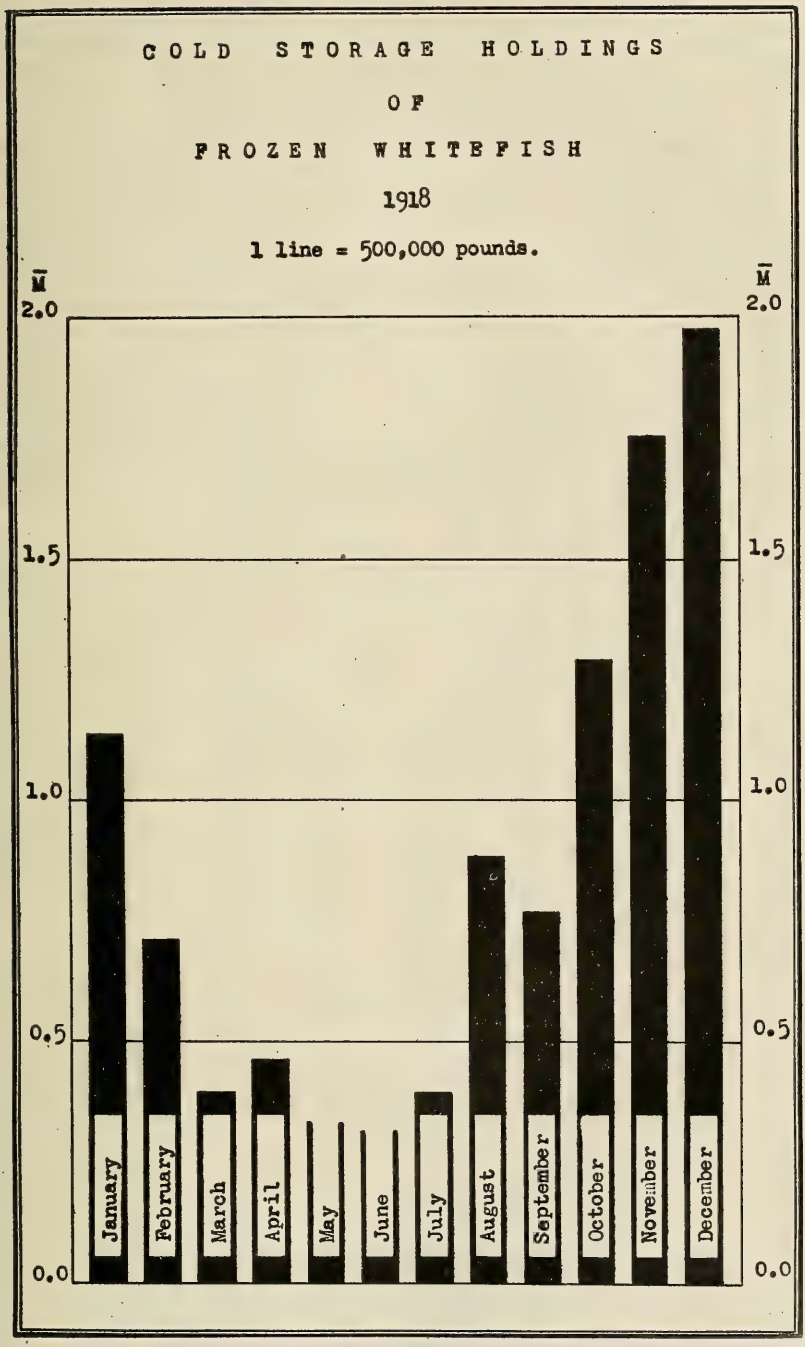
COLD STORAGE HOLDINGS
OF
FROZEN WHITEFISH
1918
1 line = 500,000 pounds.
M̄
2.0
1.5
1.0
0.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 34.

WHITEFISH.

Whitefish form one of the most important groups of fresh-water fishes of America. The common whitefish is the most valued of the tribe, although the others are highly esteemed as a food. It is found in the Great Lakes region and is known as 'humpback,' 'bowback,' and 'highback' whitefish; also as 'Otsego bass' in the neighborhood of Otsego Lake, New York. It is caught chiefly in gill nets, and averages less than 4 pounds in weight. Other economic species are the Rocky Mountain whitefish, the Menominee whitefish, also locally known as 'round whitefish,' 'frostfish,' 'shadwater,' 'pilot fish,' 'chivey,' 'blackback,' etc. The whitefishes belong to the salmon family. The name is also applied to the bluefish on the Hudson, to the menhaden in western Connecticut, to the tilefish in California, and to the beluga by whalers."

On January 1, 1,139,079 pounds of frozen whitefish remained in cold storage from the previous season. These stocks declined until June 15 and reached the low point of 312,014 pounds. The largest stocks were reported on December 15 and amounted to 1,976,681 pounds. This was 12.6 per cent more than the holdings of December 15, 1917.

TABLE 62.—*Monthly cold storage holdings of frozen whitefish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	1,139,079	57.6	−426,709	− 37.5
February	712,370	36.0	−315,116	− 44.2
March	397,254	20.1	+ 70,233	+ 17.7
April	467,487	23.7	−132,459	− 28.3
May	335,028	16.9	− 23,014	− 6.9
June	312,014	15.8	+ 80,630	+ 25.8
July	392,644	19.9	+493,742	+125.7
August	886,386	44.8	−116,785	− 13.2
September	769,601	38.9	+521,439	+ 67.8
October	1,291,040	65.3	+466,085	+ 36.1
November	1,757,125	88.9	+219,556	+ 12.5
December	1,976,681	100.0	−188,916	− 9.6

TABLE 63.—*Monthly cold storage holdings of frozen whitefish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	70	1,139,079	59	412,639	548,198	+32.9
February	79	712,370	61	264,617	357,142	+35.0
March	80	397,254	65	388,290	232,791	−40.0
April	77	467,487	62	305,970	316,504	+ 3.4
May	61	335,028	48	172,559	285,527	+65.5
June	51	312,014	39	163,617	243,683	+48.9
July	55	392,644	45	273,311	299,659	+ 9.6
August	57	886,386	48	380,702	538,503	+41.5
September	54	769,601	43	349,189	392,126	+12.3
October	66	1,291,040	58	1,571,846	1,231,502	−21.7
November	75	1,757,125	69	2,176,720	1,751,276	−19.5
December	80	1,976,681	79	1,741,026	1,960,225	+12.6

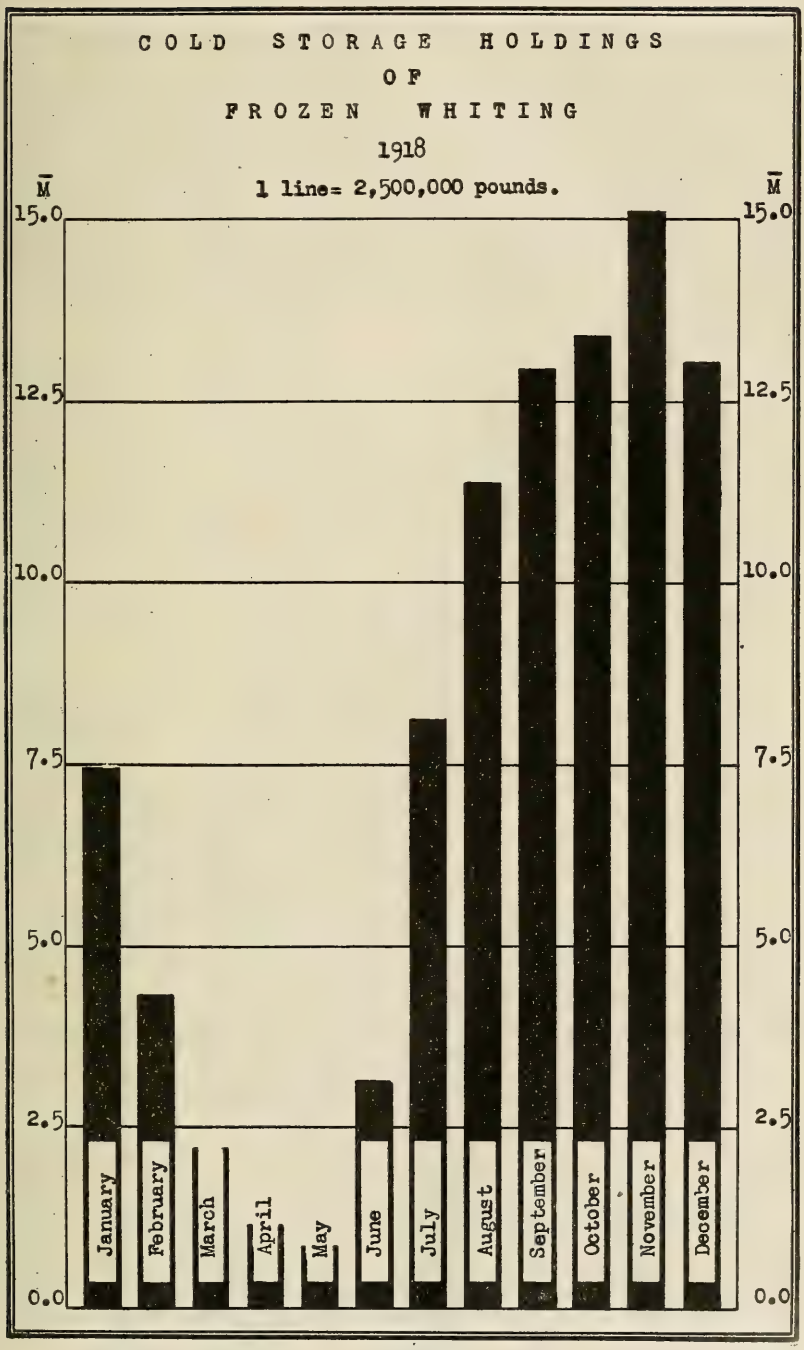
COLD STORAGE HOLDINGS
OF
FROZEN WHITING
1918
1 line= 2,500,000 pounds.
M
15.0
12.5
10.0
7.5
5.0
2.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 35.

WHITING.

"This fish is otherwise known as the 'kingfish' and 'sea-mink'; it is abundant from Cape Ann to Pensacola. The sand-whiting, also known as 'deep-water whiting,' is abundant from Chesapeake Bay to Texas. The surf-whiting, also called the 'silver-whiting,' is common from the Carolinas to Texas. The California whiting is also known as the 'sand-sucker.' On the coast of Florida they are variously known as 'kingfish,' 'barb,' 'bullhead whiting,' and 'ground mullet.' They attain a length of 10 inches and a weight of one and one-half pounds. They are caught with hook and line and in seines, and are a food fish of considerable importance. The name is also applied to the harvest-fish at Norfolk, Virginia, and to the silver hake on the New England Coast."

The holdings of frozen whiting on November 15, 1918, amounted to 15,012,968 pounds, an increase of 17.5 per cent over the stocks on November 15, 1917. With the exception of herring stocks there were more frozen whiting in cold storage at this date than of any other variety. They amounted to approximately 14 per cent of all fish frozen during the year. The lowest stock reported was on May 15, when the reports showed 867,531 pounds. The holdings decreased from January 15 to May 15 and increased from May 15 to November 15.

TABLE 64.—*Monthly cold storage holdings of frozen whiting during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	7,457,961	49.7	−3,150,071	− 42.2
February	4,307,890	28.7	−2,111,536	− 49.0
March	2,196,354	14.6	−1,046,124	− 47.6
April	1,150,230	7.7	− 282,699	− 24.6
May	867,531	5.8	+2,262,608	+260.8
June	3,130,139	20.8	+4,981,654	+159.2
July	8,111,793	54.0	+3,234,999	+ 39.9
August	11,346,792	75.6	+1,565,862	+ 13.8
September	12,912,654	86.0	+ 496,770	+ 3.8
October	13,409,424	89.3	+1,603,544	+ 12.0
November	15,012,968	100.0	−1,997,102	− 13.3
December	13,015,866	86.7	−2,790,660	− 21.4

TABLE 65.—*Monthly cold storage holdings of frozen whiting during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	94	7,457,961	77	2,572,581	5,462,105	+112.3
February	101	4,307,890	79	935,435	2,458,416	+162.8
March	109	2,196,354	87	393,300	958,091	+143.6
April	102	1,150,230	85	140,089	599,778	+328.1
May	73	867,531	59	128,364	517,662	+303.3
June	69	3,130,139	54	4,564,823	2,522,827	− 44.7
July	74	8,111,793	60	9,046,728	7,413,594	− 18.1
August	75	11,346,792	61	10,905,627	10,592,141	− 2.9
September	70	12,910,654	55	9,931,049	11,848,235	+ 19.3
October	72	13,409,424	67	11,424,723	12,764,202	+ 11.7
November	77	15,012,968	76	12,339,486	14,495,768	+ 17.5
December	86	13,015,866	85	11,498,434	12,997,666	+ 13.0

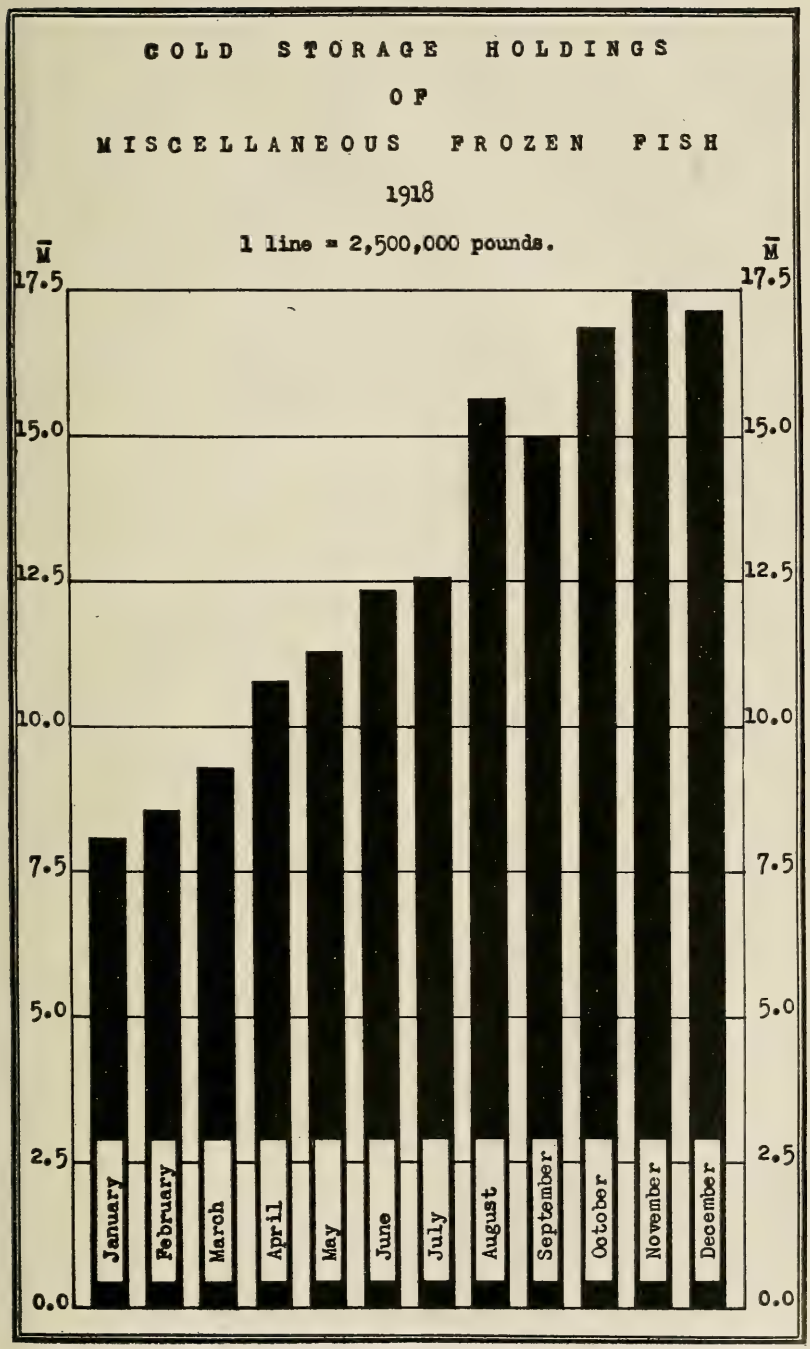
COLD STORAGE HOLDINGS
OF
MISCELLANEOUS FROZEN FISH
1918
1 line = 2,500,000 pounds.
M
17.5
15.0
12.5
10.0
7.5
5.0
2.5
0.0
January
February
March
April
May
June
July
August
September
October
November
December

FIG. 36.

MISCELLANEOUS FISH.

The stocks of miscellaneous fish increased from approximately 8,000,000 pounds on January 15 to 17,500,000 on November 15. More than 16 per cent of the total stocks of frozen fish were included in the miscellaneous group. The holdings on November 15 were 81.7 per cent greater than those on November 15, 1917.

In Table 68 are grouped the total holdings of frozen fish during each month in 1918. This table shows that the smallest quantity stored was on April 15 and the largest quantity on November 15. The holdings of the former date are 26,548,472 pounds and of the latter date 99,631,789 pounds. The holdings of November 15 were an increase of 37.2 per cent over those of the previous year. The greatest increase was from May 15 to June 15 and the greatest decrease was from January 15 to February 15.

Table 69 shows the total holdings reported for each month and a comparison of each month's holdings with those of the same date in 1917. Figure 36 is a graphic presentation of the stocks of frozen fish for each month during the year. Figure 37 represents the comparative quantities of each variety held in cold storage. For each variety is shown the maximum holdings of the year.

TABLE 66.—*Monthly cold storage holdings of miscellaneous frozen fish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	8,101,331	46.4	+ 489,894	+ 6.0
February	8,591,225	49.2	+ 731,285	+ 8.5
March	9,322,510	53.3	+1,517,119	+16.3
April	10,839,629	62.0	+ 485,190	+ 4.5
May	11,324,819	64.8	+1,073,092	+ 9.5
June	12,397,911	70.9	+ 176,930	+ 1.4
July	12,574,841	72.0	+3,092,725	+24.6
August	15,667,566	89.6	− 666,454	− 4.3
September	15,001,112	85.8	+1,887,078	+12.6
October	16,888,190	96.6	+ 588,907	+ 3.5
November	17,477,097	100.0	− 293,366	− 1.7
December	17,183,731	98.3	−2,393,819	−13.9

TABLE 67.—*Monthly cold storage holdings of miscellaneous frozen fish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	137	8,101,331	113	3,319,168	4,717,718	+ 42.1
February	148	8,591,225	117	2,764,033	4,315,066	+ 56.1
March	147	9,322,510	121	3,313,401	6,641,260	+100.4
April	148	10,839,629	128	1,862,965	7,555,764	+305.6
May	131	11,324,819	108	2,509,191	8,207,454	+227.1
June	128	12,397,911	104	4,517,987	8,833,729	+ 95.5
July	135	12,574,841	112	5,766,947	8,645,518	+ 49.9
August	138	15,667,566	115	6,057,725	9,574,236	+ 58.1
September	133	15,001,112	110	6,357,757	8,947,569	+ 40.7
October	144	16,888,190	128	9,133,346	16,035,811	+ 75.6
November	146	17,477,097	141	9,557,778	17,370,875	+ 81.7
December	153	17,183,731	149	10,692,890	17,138,951	+ 60.3

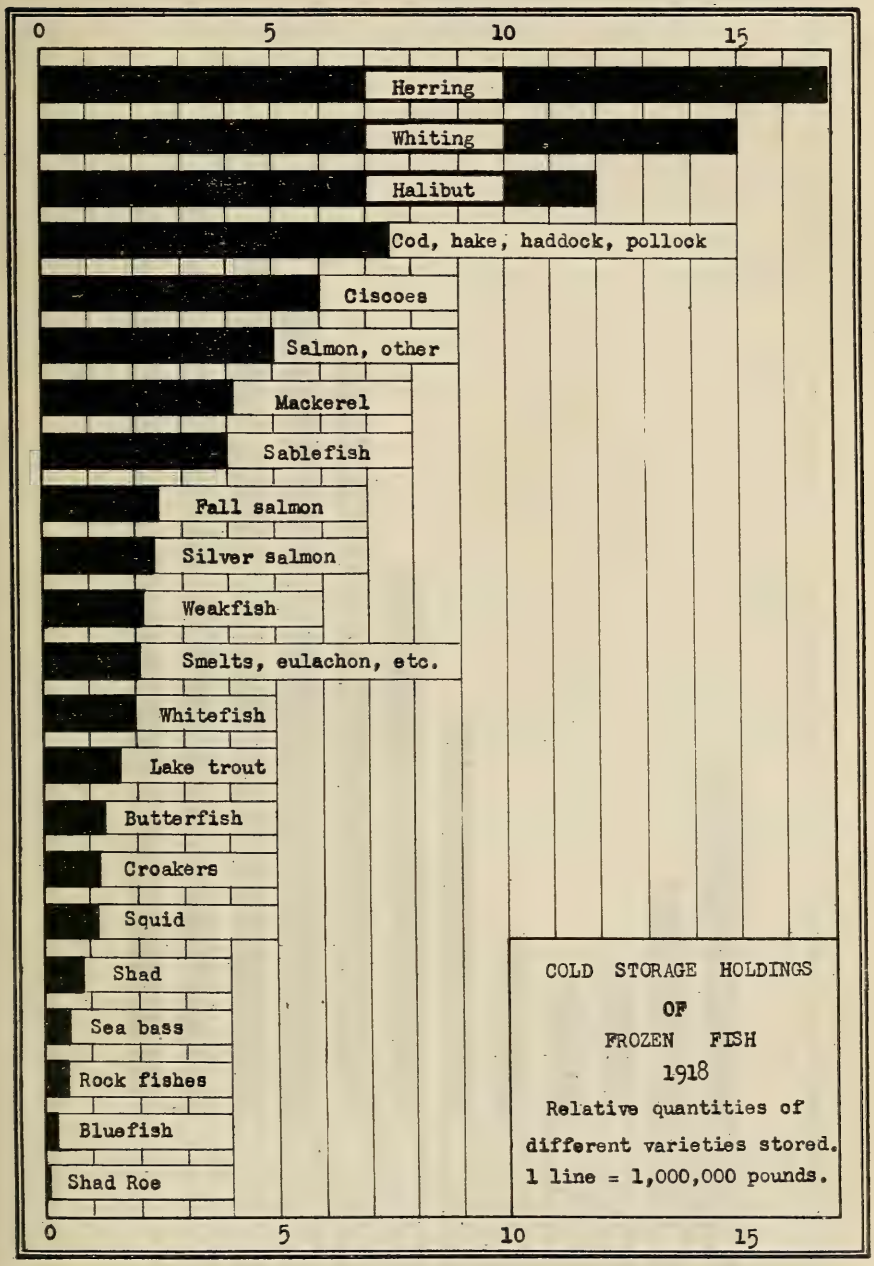
0
5
10
15
Herring
Whiting
Halibut
Cod, hake, haddock, pollock
Ciscoes
Salmon, other
Mackerel
Sablefish
Fall salmon
Silver salmon
Weakfish
Smelts, eulachon, etc.
Whitefish
Lake trout
Butterfish
Croakers
Squid
Shad
Sea bass
Rock fishes
Bluefish
Shad Roe
COLD STORAGE HOLDINGS
OF
FROZEN FISH
1918
Relative quantities of
different varieties stored.
1 line = 1,000,000 pounds.

Fig. 37.

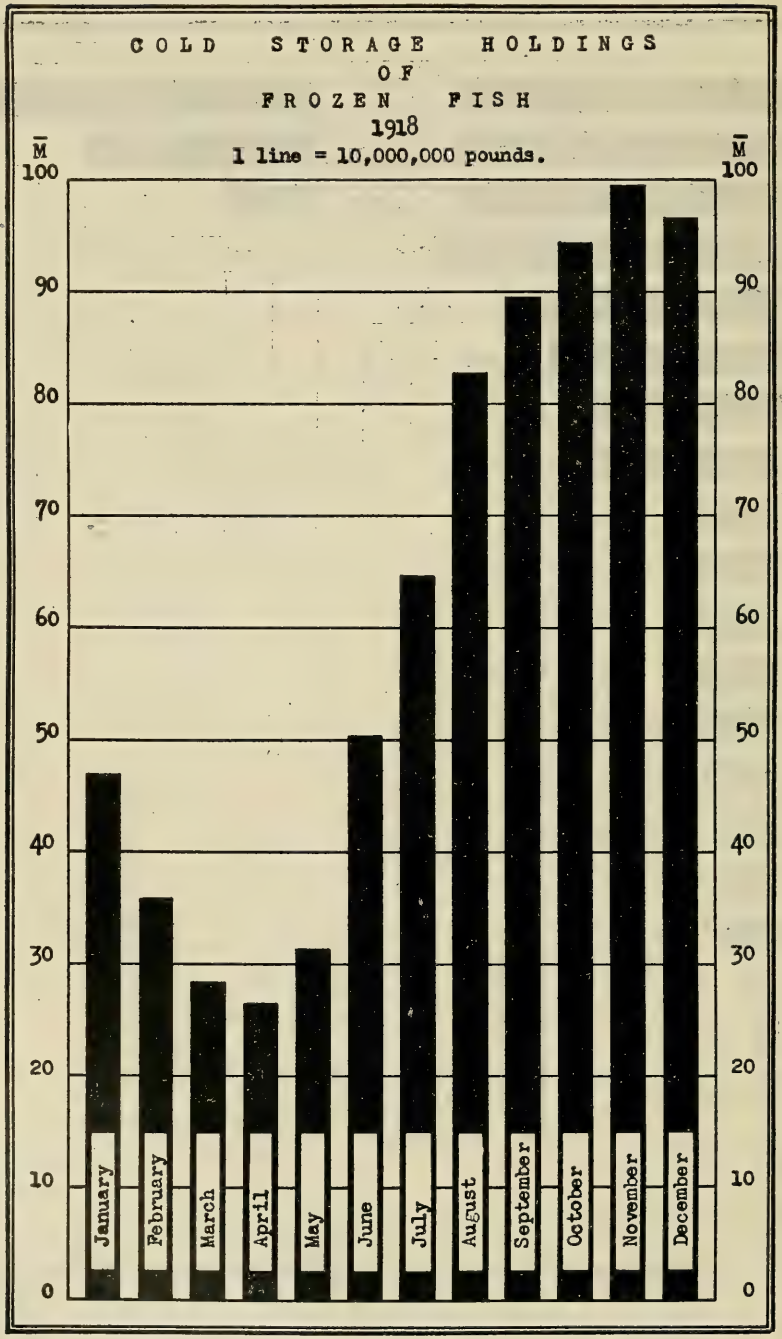
COLD STORAGE HOLDINGS
OF
FROZEN FISH
1918
1 line = 10,000,000 pounds.
M
100
90
80
70
60
50
40
30
20
10
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 38.

TABLE 68.—*Monthly cold storage holdings of frozen fish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	49,562,848	49.7	−13,655,777	−27.6
February	35,907,071	36.0	− 7,449,770	−20.7
March	28,457,301	28.6	− 1,908,829	− 6.7
April	26,548,472	26.6	+ 4,854,953	+18.3
May	31,403,425	31.5	+18,894,602	+60.2
June	50,298,027	50.5	+14,561,505	+29.0
July	64,859,532	65.1	+17,913,697	+27.6
August	82,773,229	83.1	+ 6,784,741	+ 8.2
September	89,557,970	89.9	+ 4,853,778	+ 5.4
October	94,411,748	94.8	+ 5,220,041	+ 5.5
November	99,631,789	100.0	− 3,031,542	− 3.0
December	96,600,247	97.0	−14,646,383	−15.2

TABLE 69.—*Monthly cold storage holdings of frozen fish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	177	49,562,848	144	32,234,530	36,848,447	+ 14.3
February	189	35,907,071	156	14,727,099	19,948,869	+ 35.5
March	187	28,457,301	157	13,374,429	19,869,069	+ 48.6
April	188	26,548,472	163	9,516,217	19,054,027	+100.2
May	166	31,403,425	142	14,040,294	24,238,138	+ 72.6
June	171	50,298,027	144	27,791,047	41,167,057	+ 48.1
July	176	64,859,532	149	38,431,221	52,905,689	+ 37.7
August	180	82,773,229	154	44,024,666	65,504,384	+ 48.8
September	175	89,557,970	146	47,197,660	68,497,513	+ 45.1
October	185	94,411,748	169	60,676,722	86,016,054	+ 41.8
November	192	99,631,789	185	70,938,957	97,310,173	+ 37.2
December	191	96,600,247	186	69,986,671	96,699,190	+ 38.2

REVIEW OF THE 1918 STORAGE HOLDINGS OF CURED HERRING AND MILD CURED SALMON.

CURED HERRING.

On January 15, 1918, there were almost 6,500,000 pounds of cured herring stored. The holdings decreased to 4,500,000 pounds on February 15, then increased monthly until September 15, when the stocks amounted approximately to 28,500,000 pounds. The greatest increase was 7,329,154 pounds from May 15 to June 15. The greatest decrease was 4,362,054 pounds from September 15 to October 15. The holdings of September 15, 1918, were 93.2 per cent greater than those of September 15, 1917.

TABLE 70.—*Monthly storage holdings of herring cured during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	6,455,713	22.7	−1,944,706	−30.1
February	4,511,007	15.9	+1,090,982	+24.2
March	5,601,989	19.7	+2,525,356	+45.1
April	8,127,345	28.6	+4,178,910	+51.4
May	12,306,255	43.3	+7,329,154	+59.6
June	19,635,409	69.1	+4,192,320	+21.4
July	23,827,729	83.9	+3,521,459	+14.8
August	27,349,188	96.3	+1,059,509	+ 3.9
September	28,408,697	100.0	−4,362,054	−15.4
October	24,046,643	84.6	−3,945,073	−16.4
November	20,101,570	70.8	−1,361,221	− 6.8
December	18,740,349	66.0	−3,021,387	−16.1

TABLE 71.—*Monthly storage holdings of herring cured during 1918 comp red with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	79	6,455,713	62	3,352,626	1,866,323	− 44.3
February	87	4,511,007	69	4,727,164	3,679,797	− 22.2
March	88	5,601,989	74	5,997,972	5,110,567	− 14.8
April	88	8,127,345	74	7,321,778	7,248,108	− 1.0
May	74	12,306,255	61	7,370,595	9,178,999	+ 24.5
June	76	19,635,409	63	10,389,087	14,876,177	+ 43.2
July	81	23,827,729	67	12,180,431	17,221,167	+ 41.4
August	79	27,349,188	68	12,187,193	20,709,586	+ 69.9
September	75	28,408,697	59	10,186,711	19,675,875	+ 93.2
October	83	24,046,643	72	8,816,582	23,068,351	+161.6
November	90	20,101,570	85	8,843,052	19,830,423	+124.2
December	87	18,740,349	84	7,928,363	18,713,449	+136.0

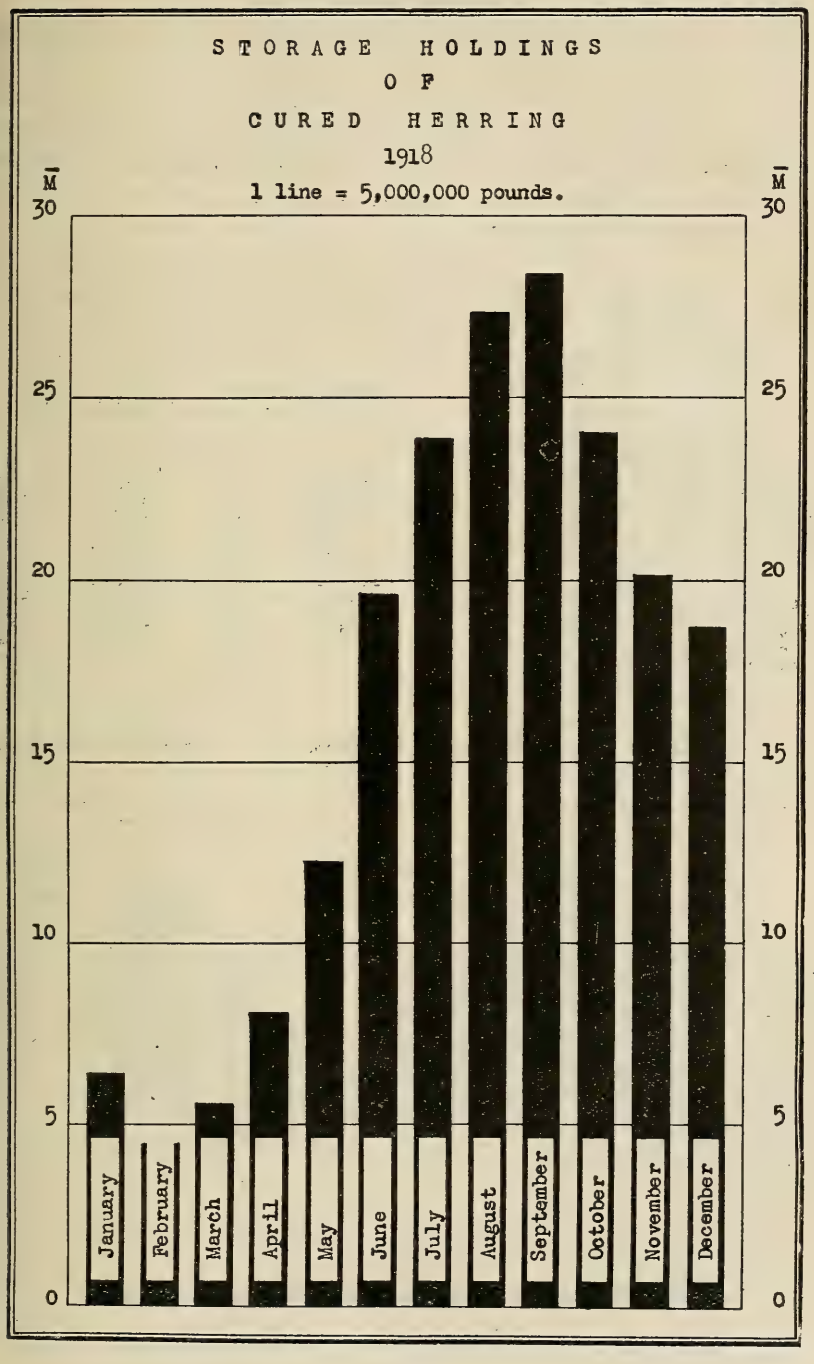
STORAGE HOLDINGS
OF
CURED HERRING
1918
1 line = 5,000,000 pounds.
M
30
25
20
15
10
5
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 3c.

MILD CURED SALMON.

The stocks of mild cured salmon on January 15, 1918, amounted to approximately 3,000,000 pounds. They decreased to 1,872,920 pounds on May 15, then increased until October 15, when the report showed 7,123,756 pounds. This was 28.2 per cent more than the quantity stored on October 15, 1917. The greatest increase occurred from July 15 to September 15, the increase during these months being more than 3,500,000 pounds.

TABLE 72.—*Monthly storage holdings of mild cured salmon during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	2,993,133	42.0	− 95,020	− 3.2
February	2,898,113	40.7	− 510,623	−17.6
March	2,387,490	33.5	− 403,355	−16.9
April	1,984,135	27.9	− 111,215	− 5.6
May	1,872,920	26.3	+ 277,819	+14.8
June	2,150,739	30.2	+ 838,277	+39.0
July	2,989,016	42.0	+2,160,795	+72.3
August	5,149,811	72.3	+1,427,058	+27.7
September	6,576,869	92.3	+ 546,887	+ 8.3
October	7,123,756	100.0	− 218,998	− 3.1
November	6,904,758	96.9	− 232,610	− 3.4
December	6,672,148	93.7	− 801,684	−12.0

TABLE 73.—*Monthly storage holdings of mild cured salmon during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	51	2,993,133	43	3,480,362	2,290,198	−34.2
February	55	2,898,113	45	3,936,370	2,597,026	−34.0
March	55	2,387,490	48	2,729,941	1,977,408	−27.6
April	52	1,984,135	43	2,583,538	1,593,045	−38.3
May	48	1,872,920	41	2,245,249	1,522,497	−32.2
June	49	2,150,739	43	2,174,066	1,453,851	−33.1
July	51	2,989,016	44	2,249,416	1,912,394	−15.0
August	53	5,149,811	47	3,746,727	4,191,811	+11.9
September	46	6,576,869	40	3,587,187	3,892,719	+ 8.5
October	49	7,123,756	43	5,112,937	6,557,023	+28.2
November	52	6,904,758	49	4,716,159	6,891,518	+46.1
December	49	6,672,148	47	4,545,784	6,670,818	+46.7

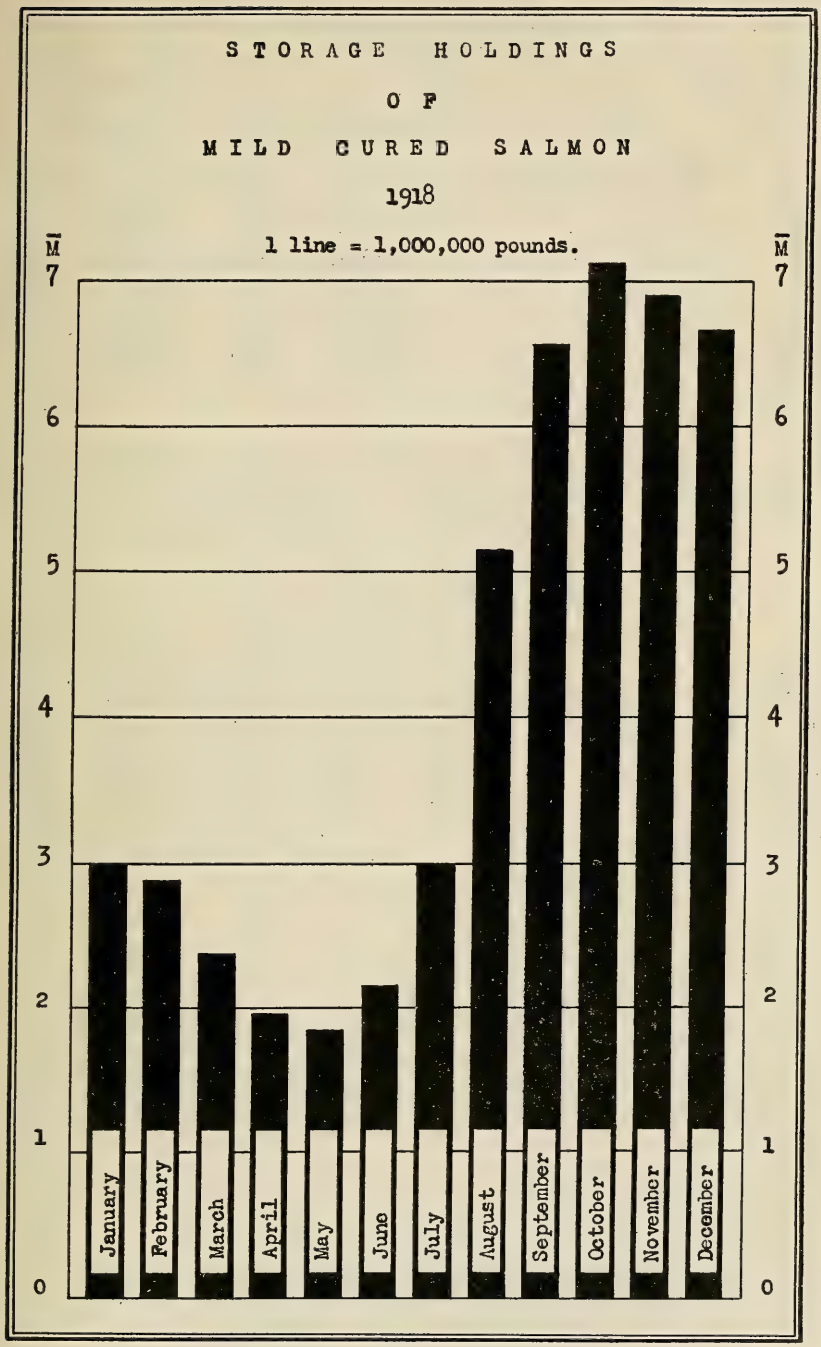
STORAGE HOLDINGS
OF
MILD CURED SALMON
1918
1 line = 1,000,000 pounds.
M
7
6
5
4
3
2
1
0
January
February
March
April
May
June
July
August
September
October
November
December

Fig. 40.

TABLE 74.—*Monthly storage holdings of fish during 1918, and increase or decrease during each month.*

Month.	Holdings on fifteenth of month.	Relative percentage.	Increase or decrease during month.	
	Pounds.	*Per cent.*	*Pounds.*	*Per cent.*
January	59,011,694	46.6	−15,695,503	−26.6
February	43,316,191	34.2	− 6,869,411	−15.9
March	36,446,780	28.8	+ 213,172	+ 0.6
April	36,659,952	28.9	+ 8,922,648	+24.3
May	45,582,600	36.0	+26,501,575	+58.1
June	72,084,175	56.9	+19,592,102	+27.2
July	91,676,277	72.4	+23,595,951	+25.7
August	115,272,228	91.0	+ 9,271,308	+ 8.0
September	124,543,536	98.3	+ 1,038,111	+ 0.8
October	125,581,647	99.2	+ 1,056,470	+ 0.8
November	126,638,117	100.0	− 4,625,373	− 3.7
December	122,012,744	96.3	−18,469,454	−15.1

TABLE 75.—*Monthly storage holdings of fish during 1918 compared with those of 1917.*

Month.	Reported for 1918.		Comparison with 1917.			
	Storages reporting.	Holdings reported on fifteenth of month.	Storages reporting for both dates.	1917.	1918.	Increase or decrease.
	Number.	*Pounds.*	*Number.*	*Pounds.*	*Pounds.*	*Per cent.*
January	177	59,011,694	144	39,067,518	41,004,968	+ 5.0
February	189	43,316,191	156	23,390,633	26,225,692	+12.1
March	187	36,446,780	157	22,102,342	26,977,044	+22.1
April	188	36,659,952	163	19,421,533	27,895,180	+43.6
May	166	45,582,600	142	23,656,138	34,939,634	+47.7
June	171	72,084,175	144	40,354,200	57,497,085	+42.5
July	176	91,676,277	149	52,861,068	72,039,250	+36.3
August	180	115,272,228	154	59,958,586	90,405,781	+50.8
September	175	124,543,536	146	60,971,558	92,076,107	+51.0
October	185	125,581,647	169	74,606,241	115,641,428	+55.0
November	192	126,638,117	185	84,498,168	124,032,114	+46.8
December	191	122,012,744	186	82,460,818	120,083,457	+45.6

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 793

Contribution from the Bureau of Biological Survey,
E. W. NELSON, Chief.

Washington, D. C. PROFESSIONAL PAPER. July 31, 1919

LEAD POISONING IN WATERFOWL.

By ALEXANDER WETMORE, *Assistant Biologist.*

CONTENTS.

INTRODUCTION.

Lead poisoning in various species of wild ducks and other waterfowl has recently attracted attention among persons interested in game birds in the United States. Though for a number of years this disease has been reported in periodicals devoted to sport and from other sources, it is little recognized and understood, and few sportsmen have any knowledge of it. Already it is causing the loss of a considerable number of waterfowl each year, and there is no doubt that as time goes on it will assume greater importance. Lead poisoning in waterfowl has its origin in the large quantity of expended shot that from year to year is deposited in the mud about shooting points and blinds in marshes, shallow bays, and lakes. Birds find and swallow these leaden pellets while searching for food, and many are seriously affected by the poison thus taken. Present knowledge indicates that the mallard, canvas-back, and pintail ducks and whistling swans have suffered most, but a number of other species will probably be included in the list when the matter is more fully investigated.

Many opportunities have come to the writer to handle and examine ducks and other birds suffering from lead poisoning during the past three years, and he has had occasion to carry on experiments to ascertain the cause and manner of the affection. The results are outlined in

NOTE.—This bulletin is a report of studies made of a serious malady among ducks and other waterfowl in the United States. It is for the information of sportsmen, naturalists, and others interested in game birds.

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the following pages. During the course of the work the Bureau of Chemistry has cooperated in making analyses to determine the presence of lead in portions of the viscera of affected birds.

HISTORY.

At various times during past years there has been discussion in sporting magazines regarding the presence of shot in the stomachs of wild ducks. More recently attention was called to lead poisoning in ducks by J. H. Bowles[1] in 1908. On the Nisqually Flats, a large marsh area in the Puget Sound district, Washington, a number of mallards had been found sick or dead. Examination of three of these revealed a quantity of shot still held in the gizzard. The Nisqually Flats have been famous ducking grounds since early settlement in the State, so that it may be supposed that shot are present in the mud in abundance.

Lead poisoning was reported in 1908, also, among canvas-back ducks on Lake Surprise, Tex., and an account of it was published by W. L. McAtee, of the Biological Survey.[2] Lead poisoning in this locality apparently had been known for several years. It was stated that canvas-backs resorted to Lake Surprise in November each year, and affected birds appeared in the rushes along shore about the first of January, while as the season advanced these sick birds died and disappeared. From all accounts, no other species of ducks were affected here.

Examination of several whistling swans from Back Bay, Va., sent to the Biological Survey during January, 1915, showed that these birds were suffering from lead poisoning, as from 22 to 45 shot pellets were found in the gizzard of each. On inquiry it was learned that sick swans were found in January every year, and that the trouble among them continued until March. The malady, known locally as the "keuk," was said to affect canvas-backs and other ducks and geese as well as swans.

During the summers of 1915 and 1916, while working in the marshes formed in the Bear River Delta at the northern end of Great Salt Lake, Utah, the writer handled many ducks suffering from lead poisoning. Here the species affected were mallards and pintails, the majority being males. Birds sick from poisoning were found from June to September, and the total number that died was considerable, though insignificant when compared with the numbers destroyed here by other diseases.

Reports of sick ducks in other localities in the United States seem to indicate lead poisoning as the causative agent, but material has not as yet been available to substantiate this. It is believed that the trouble is more or less prevalent throughout the country.

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[1] Auk, XXV, pp. 312–313, 1908. [2] *Idem*, p. 472, 1908.

SPECIES OF BIRDS AFFECTED.

The list of species of birds at present known to have been poisoned by eating shot is small, but it will undoubtedly be increased when the facts are better known. In the following brief list all but one species (the canvas-back) are included from personal observations of the writer:

Mallard (*Anas platyrhyncha*).
Pintail (*Dafila acuta tzitzihoa*).
Canvas-back (*Marila valisneria*).
Whistling swan (*Olor columbianus*).
Marbled godwit (*Limosa fedoa*).

Lead poisoning is a common affection in all these except the marbled godwit. Only one specimen of this bird that had died from eating shot has been examined. In this species and in other shore-birds lead poisoning is probably rare. Geese and several species of ducks in addition to those listed above are said to have been affected in various localities, in particular on Back Bay, Va., but these reports have not as yet been investigated.

As has been stated, the shot secured are taken while feeding. Pintails and mallards delight in working in shallow water, where they dig away the mud to a depth of 6 to 18 inches, in search of succulent roots and tubers. In this manner they work over extensive areas, forming "duck holes" from 1 to 15 feet or more in diameter. Swans feed in much the same manner, but, with their long necks, are enabled to work in deeper water. The canvas-back is a diving species that digs constantly in the bottom mud and frequently feeds at a considerable depth. With all these birds certain quantities of gravel or grit of some kind are necessary for the proper grinding, or trituration, of food in the gizzard to put it in proper form for the extraction of nutriment. In the mud of marshes and lowland lakes little gravel is present, and to secure this needed element the birds in feeding develop a tendency to swallow any small, hard object they encounter. In this way the shot that have accumulated about shooting points are swallowed one by one. The bird may be several days or even longer in securing a fatal dose or it may pick up a large number of pellets at one time. In either case the shot are held in the gizzard to be slowly ground away, only small particles of lead passing on into the intestine.

SYMPTOMS OF LEAD POISONING.

The symptoms of lead poisoning as observed in waterfowl are similar in many ways to those found in mammals. A prominent indication of this malady is a paralysis of important muscles, which increases steadily as the ailment progresses. This paralysis seems first to affect the nerves supplying the great pectoral muscles of the

breast, and in a very short time the birds are unable to fly. (Pl. I, figs. 1 and 2.) Following this the wings begin to droop from the sides. In many cases the extensor muscles supporting the wing tip, that portion of the fore limb homologous with the hand, are seriously affected, and the wing hangs from the carpal joint, a symptom strikingly like the "wrist drop" found in many cases of lead poisoning in man. The wings float loosely on the surface when the affected birds are in the water, and in severe cases the tips of the primaries may drag as the bird walks about on the ground. Other muscles are affected as well. When the bird is standing, the breast is depressed and the tail droops. (Pl. II, fig. 2.)

After a few days birds often experience difficulty in walking and may fall as they attempt to turn around. This paralysis of the legs grows until the body can no longer be supported, and in moving about the birds slide along on the breast. (Pl. I, figs. 1 and 2.) This loss of function in the muscles is not always symmetrical; in several cases muscles on the left side were more severely affected than on the right. This was especially noted in the leg muscles. In many of the living birds studied the poisoning due to ingested shot was acute, and death came in a few days. In others the condition became chronic, and the birds, much emaciated, lived from two to five weeks. Often an adult mallard would waste away until the large muscle masses of the breast were reduced to slender fasciæ that were barely sufficient to cover the sternum.

The feces of affected birds are thin and watery and stained green. This color is a well-marked symptom. When fecal matter comes largely from the rectum the green is very dark, but when mixed with renal matter in the cloaca it becomes paler. In this case the green color, though lighter, is remarkable for its brightness. The body temperature of affected birds is normal, unless the individual is anaemic, when it is subnormal.

In weak birds the eye was usually very bright and the muscle controlling the nictitating membrane not affected. During field work in Utah this point was used as a ready means of distinguishing these birds from individuals helpless from poisoning due to alkalies.[1]

The heart of a bird suffering from lead poisoning is affected, and the bird may die suddenly after fright or exertion. Captives under observation were liable to spasms after they had become much weakened, during which they fell on the breast with head and wings extended, and were agitated by slight but rapid tremors. In some cases this caused the lower mandible to rattle against the upper. These spasms were followed by periods of weakness, when for a time the birds lay motionless, but later were able again to walk about. The

[1] Cf. Wetmore, Alexander. The Duck Sickness in Utah: Bull. 672, U. S. Dept. Agr., pp. 1–25, 1918.

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FIG. 1.—MALLARD WITH LEAD POISONING.

The carpal joint of the wing is affected, simulating "wrist drop," and the bird has difficulty in walking.

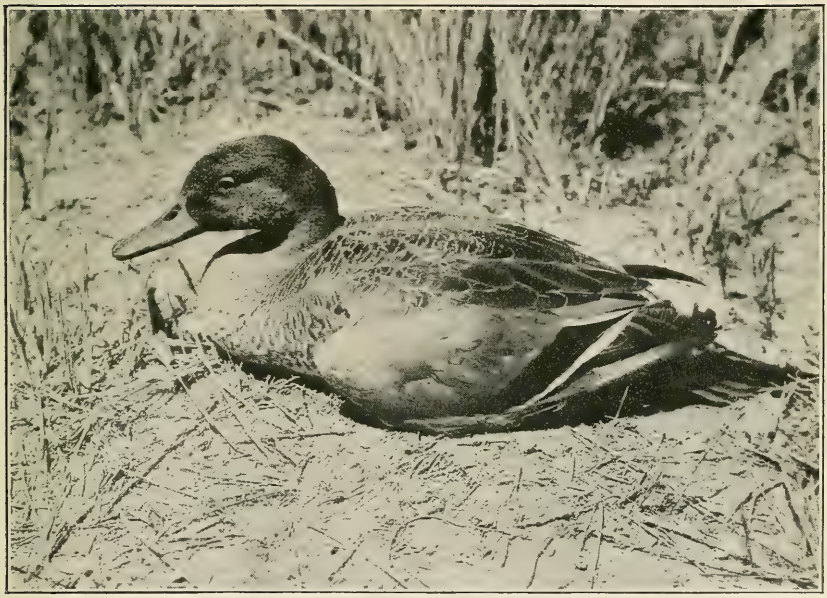

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FIG. 2.—PINTAIL WITH LEAD POISONING.

Paralysis of the legs renders the bird unable to stand.

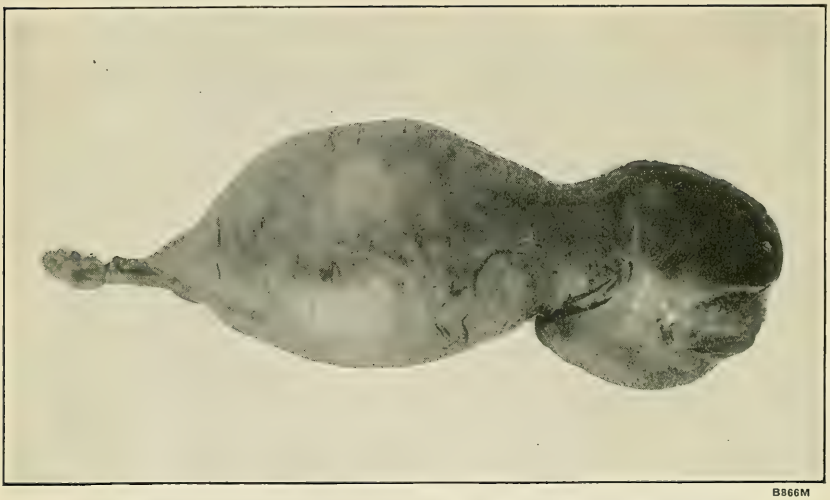

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FIG. 1.—STOMACH OF MALLARD THAT DIED FROM LEAD POISONING.

Abnormal distension of lower œsophagus and proventriculus with food produces a mass larger than the gizzard.

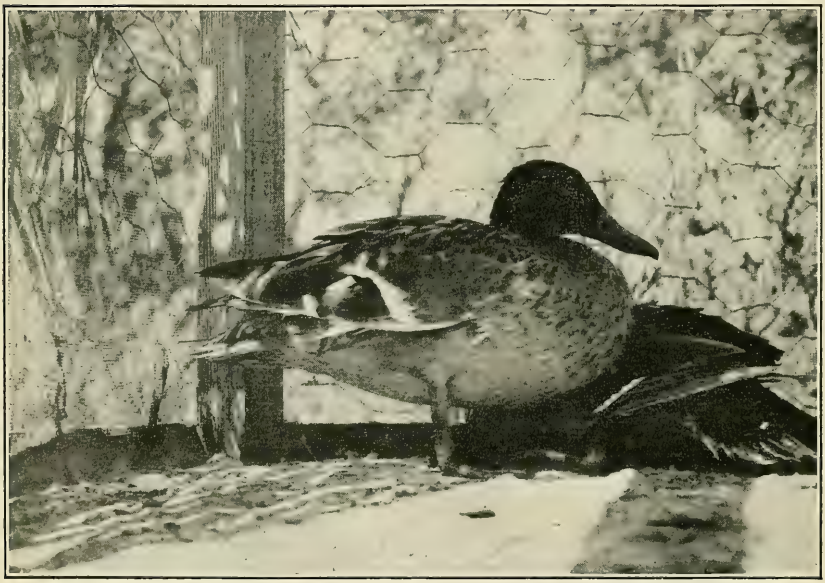

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FIG. 2.—MALLARDS WITH LEAD POISONING.

The breast is depressed and the tail droops when the bird is standing. In health the carriage is more erect.

heart seemed to be affected seriously, and the pulse in many cases was rapid and very strong. In one instance the heartbeat of a male mallard under observation in the laboratory was distinctly audible at a distance of 10 feet, but this was unusual. It was found that birds thus affected were liable to die after any fright or exertion that stimulated the heart action strongly. In one instance a mallard in the water dived to escape capture, and remained beneath the surface for 30 seconds. It came up, and attempted to dive again, but suddenly relaxed, and was dead. In other instances birds kept in experiment pens died while being handled. Death frequently came during the spasms described above.

Birds with lead poisoning always had good appetites, and ate eagerly. Often when they were so weak as to be unable to stand, the gullet and upper portion of the stomach were found to be crammed with food. These birds drank copiously and at short intervals. When disturbed they often regurgitated quantities of greenish fluid, a watery discharge that stained the mouth cavity and the tongue. No solids came with this. Birds of the groups affected are, in so far as the writer's experience is concerned, unable to return solids that have been swallowed.

POST-MORTEM APPEARANCE.

The flesh of birds dead from lead poisoning is in nearly all cases pale. This pallor was well marked in ducks that had been sick for some time, and occurred before a wasting of the muscles began. In chronic cases in which emaciation was extreme there was a marked pallidness of the larger muscle masses, and even of the viscera. The blood was slow to coagulate, and frequently remained fluid for 10 or 12 hours after death. Studies made of blood taken from living birds indicated a decrease in the number of red corpuscles, but as the apparatus used in making blood counts was imperfect, results from these examinations were far from satisfactory. At that time perfect counting chambers for the usual grades of hæmacytometers were not available on the market, so that conclusive studies of the effect of lead poisoning on the blood are yet to be made.

Examination of blood smears has failed as yet to show the presence of granules that have been noted in the case of lead poisoning in mammals. The heart generally was in systole. In case the bird examined had become weakened while in the water, so that actual death came through drowning, the ventricles were in diastole as is usual in birds that have drowned, but this was an abnormal condition. In chronic cases of a week or more in duration the pericardium was usually distended with a watery lymph, slightly tinged with brownish orange.

During prolonged cases of lead poisoning, the alimentary tract exhibited several changes that were characteristic of the trouble. In normal birds the ventriculus, or gizzard, and the crop may be crammed with food, but the proventriculus, or glandular portion of the stomach, is empty. In cases of lead poisoning from eating shot the appetite for food is greatly increased, while the gizzard seems slow in action, and observations indicate that the great muscles in its walls are more or less paralyzed. In these birds the proventriculus and the lower portion of the oesophagus are greatly distended with food, so that they form a mass larger than the gizzard itself and have their walls stretched to the utmost. (Pl. II, fig. 1.)

The pads lining the inside of the gizzard often appear more or less corroded and slough easily, while gravel may work up into the lower portion of the proventriculus, a condition that is unknown in the healthy animal. The contents of the gizzard were usually stained green. Occasionally this color extended through the food contained in the lower part of the proventriculus.

Generally the shot were found on washing out the matter contained in the gizzard, though a few were located in the lower end of the proventriculus. The usual number of shot in one stomach was 15 to 40. The largest number of pellets taken from one bird was 76, found in the gizzard of a mallard secured near the mouth of the Bear River, Utah. In September, 1916, during routine laboratory work, 28 mallards and 10 pintails that had died from lead poisoning were examined. From the stomachs of these 38 birds 939 shot were recovered, an average of a fraction less than 25 each. Where shot have been in the gizzard for a considerable time they are much worn, and in many cases are ground down to flattened disks by the action of the stomach muscles and the trituration with gravel.

The intestine may be irritated, or may be nearly free from distended capillaries. Observations on this point are uncertain, as the birds examined were from regions where the waters frequented contain irritant salts, usually in quantities sufficient to bring about a certain amount of congestion in the capillaries of the intestinal walls of the waterfowl. Where many shot are in the stomach the walls of the small intestine may be discolored, and in nearly every case there is a deposit of lead on the inner walls of the cæca. This deposit is most pronounced in the distal third of these blind guts, but may extend for their entire length. The cæcum appears lead colored from without, but when slit and examined its inner walls are found to be blackish. The gall bladder is always full and may be much distended. In one individual examined the gall bladder measured 30 mm. long by 12 mm. in diameter. The bile is very dark green, and after death this color may spread slowly until it has stained the

entire liver. This was noticed in particular in examining several whistling swans received at the Washington laboratory from Back Bay, Va.

RESULTS OF EXPERIMENTAL WORK.

During the field seasons of 1915 and 1916 a series of experiments dealing with lead poisoning in ducks was made at a field laboratory near the mouth of Bear River, Utah. Though shot had been found in many instances in the stomachs of birds, their presence had not been determined absolutely as the causative factors of the disease apparent in such individuals. The stomachs of a large number of ducks have been examined in the laboratories of the Biological Survey to determine the food habits of the species. These stomachs were from birds apparently healthy when killed. It is not unusual to find from one to half a dozen or more shot pellets in such stomachs, and in birds from certain localities pellets were almost always found. These facts cast some doubt on the supposition that ducks were affected unfavorably by eating shot, and it was necessary to test the matter by actual experiment.

For this purpose small pens 3 feet wide, 3 feet high, and 5 or 6 feet long were used. Each pen was placed on a platform a foot above the ground with a hole cut in one end to hold a water pan, and the boards were covered with earth. Ducks were taken from large stock pens and placed in these smaller pens as needed, while control birds were confined under similar conditions in separate pens. They were fed morning and evening on mixed grain containing wheat and barley in equal quantity.

Wild mallards, captured when young and reared to maturity, were used in the main experiments, so that there was no possibility of their having obtained shot before they were placed under close observation. Shot and lead were given to these birds through a small glass funnel. The lower end of the funnel was placed well down the duck's throat and after the shot were given a small quantity of water was poured down to insure that the pellets or particles should not lodge in the oesophagus. After treatment birds were watched closely for several minutes to make certain that none of the lead was cast out through the mouth. It was found that six pellets of No. 6 shot constituted an amount of lead that was always fatal. Two or three shot were sufficient to cause death in several instances, and as the number was increased the resistance of individual birds decreased. In one experiment two mallards were each given one No. 6 shot. One died 9 days later, while the other was able to throw off the effects of the lead and recover. Pintails and redheads were similarly affected. One male pintail was given four pellets of No. 6 and another six.

Both died, the former in 11, and the latter in 13 days. One redhead was killed by taking six No. 6 shot. Another was given four pellets of shot and was sick for some time, but finally recovered. Experiments were not tried with other species.

The symptoms in these birds were invariably the same, and it was proved beyond question that lead poisoning from ingested shot is a dangerous and usually fatal malady. In from 10 to 24 hours the feces of birds to which shot had been given were stained with green and were loose and watery in consistence. This green tinge increased until the fecal matter was very dark. Birds thus affected drank constantly, and frequently when disturbed regurgitated small quantities of more or less greenish water. As the malady progressed the affected ducks spent more and more time in the water pans and drank constantly. The excrement in 12 hours often was sufficient in quantity to color strongly 10 quarts of water.

Other symptoms and post-mortem appearances were similar to those described in previous paragraphs. Birds were affected more rapidly by soft shot than by chilled or hardened shot, but in either case the result was the same. Birds that had the stomachs well filled with gravel or that had access to an abundance of gravel were weakened more quickly than those that had been confined for some time where they could not secure grit. Apparently the rapidity with which they became affected was dependent upon the speed with which trituration in the ventriculus ground away particles of lead and passed them into the intestine. It has been mentioned that in post-mortem examinations the blackened lining of the cæca was found to be a prominent symptom of lead poisoning. It was supposed that this blackening was due to the presence of lead sulphide formed by the action of hydrogen sulphide upon lead particles present in the intestine. Analyses made in the Bureau of Chemistry proved that this was not true in the majority of cases, as only a trace of lead sulphide was detected in one sample in six submitted for examination. The quantity of lead present in the cæca seemed somewhat correlated with the number of shot in the stomach. Table I gives the results of the six analyses.

TABLE I.—*Relation between number of shot in stomachs of waterfowl and quantity of lead in cæca.*

Species.	Number of shot in stomach.	Quantity of lead detected in cæca.	Species.	Number of shot in stomach.	Quantity of lead detected in cæca.
		Mgm.			*Mgm.*
Mallard	4	0.20	Mallard	34	0.55
Do	11	.20	Do	48	.55
Do	17	.27	Pintail	5	.15

After experiments had fully established that shot were capable of poisoning waterfowl, the question as to whether the diseased condition was caused by lead or by some other substance present in the shot remained to be settled. Arsenic is a common impurity in commercial lead, and in the manufacture of shot a certain quantity is usually added. This is said to be necessary to make the lead pellets spherical when dropped and also to harden them. As arsenic and lead in combination are used to form poisonous compounds for killing insects and for other purposes, it might be supposed that these compounds were active in cases of poisoning from shot eaten and held in gizzards of waterfowl. In several experiments, therefore, ducks were given quantities of granulated lead equal in weight to the number of shot that in other cases were found to be fatal. The granulated lead had the same effect as the shot in each instance, proving that lead was the active agent in the poisoning. Birds seemed to die more quickly from the effects of the granulated lead, as the particles were numerous and so small that they were readily ground up and passed into the intestine to be absorbed.

PREVALENCE OF SHOT IN MARSH AREAS.

Many marshes, lakes, and bays in the United States are noted as resorts for waterfowl, and are visited each year during the hunting season by sportsmen in pursuit of game. Owing to the configuration of the land and water areas and the habits of the birds pursued, there are points or islands in these places that afford good shooting each season, and in many cases blinds to conceal the hunters are located on or near the same spot year after year. In time a great mass of waste shot pellets will gather about these points. The action of the water, especially where it is more or less saline or alkaline, tends to corrode these shot somewhat, but this process is in most cases very slow, so slow, indeed, as to be hardly appreciable. As corrosion takes place, there forms over the surface of the shot a scale, which, as it thickens, protects the lead more and more from further chemical action. There can be no question that shot pellets may last for many years.

To ascertain the presence of quantities of expended shot in these marsh areas the writer with an assistant examined the mud near two localities in the shooting grounds at the mouth of Bear River, Utah, from each of which several thousand shells are fired each season.

For the first experiment a small island known as Bayless Island was selected, on which a blind had been placed each season for about 20 years. In searching for shot an ordinary sieve with a mesh small enough to hold No. 7 shot was used. Mud was shoveled into this and washed through the wire. The mud here was soft for a depth of 5 inches; below this was a hardened clay. Sifting was begun at

a point 30 yards from the blind and was continued at 20-yard intervals in a straight line out from the shore to a distance of 210 yards from the island. About 10 quarts of silt were examined from each spot. Shot first appeared at a point 70 yards out and were found at each station to the place where sifting was stopped. The pellets were most abundant at a distance of 130 yards, where from 1 to 12 were recovered in each sieve filled with mud.

On another day sifting was tried near Bigelow's Point, a locality about 2 miles west of Bayless Island. Here a blind had been located on a small island for at least 20 years, and another island 200 yards south had been used as a shooting stand for the same period. In addition to these, many temporary boat blinds have been built in the open bay offshore. Sifting was carried on here in the same manner as at Bayless Island in a line that included ground within shotgun range of both blinds. The first mud was examined at a distance of 30 yards from Bigelow's Point, and sifting was continued at 20-yard intervals for a distance of 230 yards. Shot were secured from each sifting for the entire distance and from 1 to 13 pellets were found at each station. At stations more than 150 yards from the blind, from 20 to 22 shot were recovered from each of three lots of mud taken at one point. The surface mud here was very soft for a depth of 12 inches, below which was a hardened clay. The great mass of shot had penetrated through the soft surface layer of mud and lay at a depth of 10 to 12 inches.

On this entire marsh there can be no question that 75,000 or more shotgun shells are used each season. As each shell contains approximately an ounce of shot, the great accumulation of the lead pellets about blinds that are favorably located may be imagined readily. The majority of the shot that were recovered by sifting were soft; only a small part were chilled. This may serve to indicate that a large part are comparatively old, as at present chilled-shot loads are used. The soft shot in question were all more or less battered and scarred from muzzle compression as they left the gun or from other causes. All were dulled in color, indicating slight surface oxidation, but none showed any distinct corrosion, though the clay below the softer mud was often strongly saline.

These facts point to a steadily increasing body of shot pellets in the mud of these marshes, as there are undoubtedly in other marshes on which shooting is extensive.

CONCLUSIONS.

From his own observations and from others the writer has learned that lead poisoning due to eating shot is of common occurrence among waterfowl, and from the manner in which the shot are se-

cured it seems reasonable to suppose that this disease will continue and will increase as time goes on. It seems probable that cases of lead poisoning may be found among upland game birds, as pheasants thus affected have been known for many years on extensive shooting preserves in England.[1] Diseased birds were usually found on such estates a short time after the close of the hunting season, and from 1 to 3 shot pellets have been taken from the gizzards of sick pheasants examined.

A point that may develop greater importance than the direct killing of individual birds by lead is the effect that lead may have upon the constitution and bodily functions of birds that do not actually succumb to its poisonous properties. It is well known that lead acts as an abortifacient in females of mammals. No information on its action in female birds during the breeding season is at hand. In experiments performed by L. J. Cole, at the Wisconsin Experiment Station, it was found that lead administered to male domestic fowls had a powerful effect upon their virility.[2] This was indicated by infertility of many eggs and a high percentage of deaths in embryos and in young chicks soon after hatching. Lead poisoning in the male in these cases distinctly affected the vitality of the offspring. If it should be found that lead poisoning affects males of wild ducks and other waterfowl in a similar manner, this may prove to be a factor of importance in the diminishing numbers of these birds. In such cases the poison will be of detriment even in those birds that seem tolerant of its effects.

At the present time all that can be done in regard to lead poisoning is to call attention to its prevalence and to describe its cause and symptoms, that they may be understood by persons finding birds thus affected. No suggestions of a practical nature can now be made to alleviate this danger to our waterfowl. The writer has been able to effect a cure in a few individuals by treating them with magnesic sulphate. Wild birds that were brought into the laboratory with lead poisoning were confined in small pens, where they were supplied with a solution containing 60 grams of magnesic sulphate in 10 quarts of water. This was renewed daily. As magnesic sulphate forms an insoluble compound with lead, this solution tended to neutralize the lead particles as they were given off into the intestine. The color of the feces in birds treated changed at once from bright green to olive brown. This treatment was tried on a small number of ducks, and about 50 per cent recovered. The method is of interest as an experiment but has little or no practical value, as the time required for treatment was prolonged and the result was somewhat uncertain.

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[1] Cf. The Field (London), vol. 47, pp. 189, 267, 1876; and vol. 59, p. 232, 1882.
[2] Wisconsin Exp. Sta., Bull. 250, pp. 44–45, 1915.

Various suggestions have been made to combat this trouble but none is at all efficacious. Some persons, supposing that the birds swallowed the shot because of a lack of gravel on their feeding ground, have proposed supplying grit and sand in the marshes in the belief that the birds would use this and not eat the shot. As has been said before, ducks in feeding seem to swallow any small, hard objects that they encounter, so that such supplies of gravel would be of no aid in preventing lead poisoning. It has also been suggested that the mud flats be harrowed in some way to cause the shot to sink beyond reach. This, however, would be of no avail, as ducks in feeding often dig in soft mud to a depth of 12 to 16 inches.

Statistics on the number and species of birds affected by lead poisoning from eating pellets of shot will be of interest, and it is hoped that sportsmen and others will report cases that come to their attention. There can be no doubt that the trouble is found in many extensive marsh areas throughout the United States in addition to those mentioned in this report.

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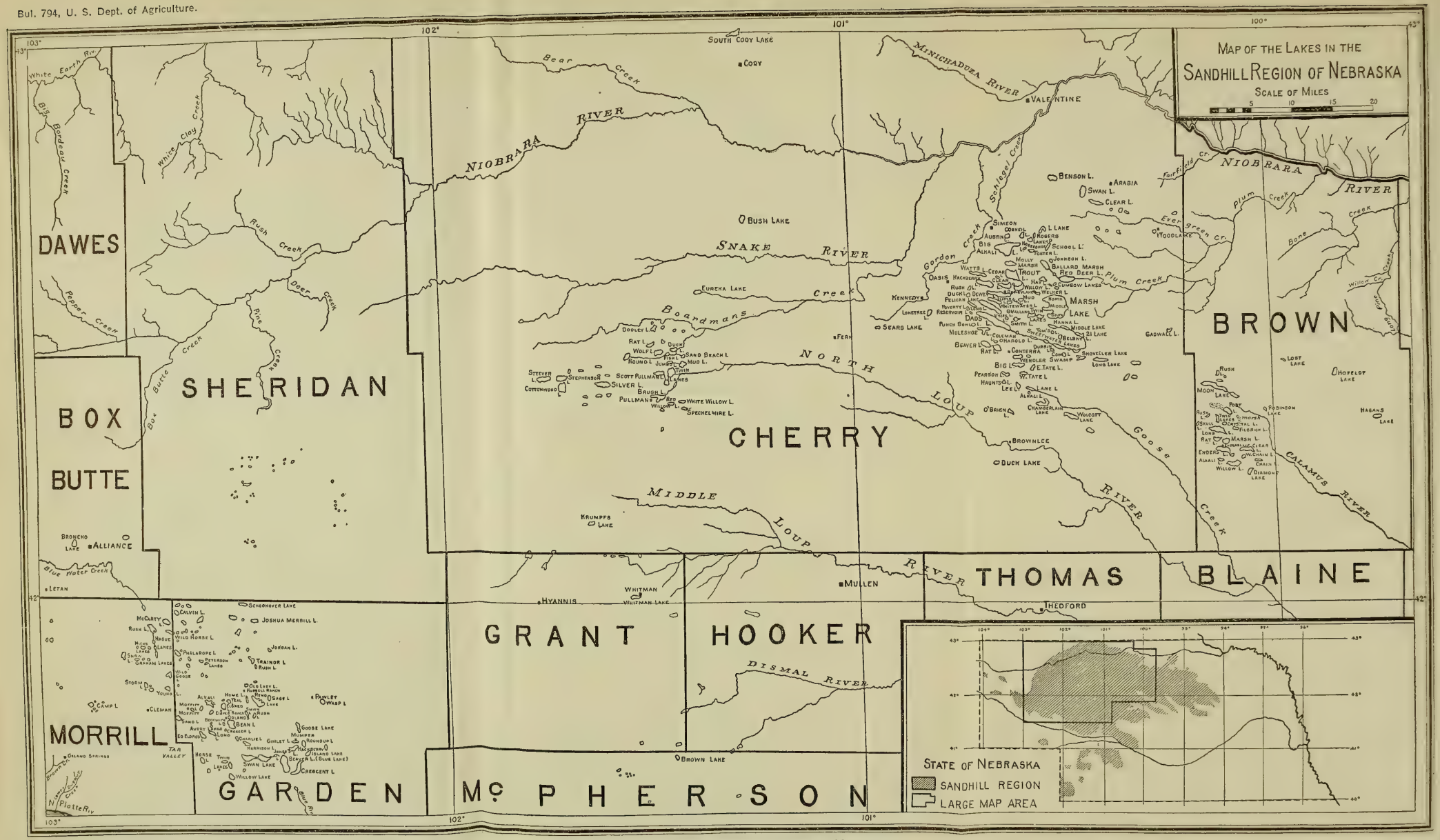

MAP OF THE LAKES IN THE SANDHILL REGION OF NEBRASKA.

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 794

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

Washington, D. C. PROFESSIONAL PAPER. March 23, 1920

WATERFOWL AND THEIR FOOD PLANTS IN THE SANDHILL REGION OF NEBRASKA.

By HARRY C. OBERHOLSER and W. L. MCATEE, *Assistant Biologists.*

CONTENTS.

GENERAL INTRODUCTION.

Throughout the United States the draining of marshes and shallow lakes has proved during recent years a menace to the preservation of waterfowl. Many of these lakes were formerly the homes of countless wild fowl during both the breeding season and the migrations, but so general has the draining of lakes and marshes become that the remaining available resorts for these birds are becoming more and more limited. It is of the greatest importance, therefore, that accurate knowledge regarding the condition of the present breeding and wintering grounds be secured, in order that steps may be taken before it is too late to conserve the remaining supply of waterfowl inhabiting these areas. In view of the constant diminution in the numbers of our waterfowl and the consequent menace to the continuance of duck hunting as a sport, as well as to the very existence of the birds themselves, the protection of waterfowl on their breeding grounds becomes a matter of prime necessity.

The Biological Survey has long recognized this need, and is making efforts to ascertain the exact conditions prevailing on the

breeding grounds of waterfowl in various parts of the United States. This is by no means an unimportant part of the inventory of our natural resources which is so necessary if we are to take intelligently directed steps toward passing on what remains of our heritage of natural wealth.

Efforts to increase the numbers of native waterfowl may be grouped in two main divisions: (1) Protection by legislation, which will save what breeding stock we have and give it a chance to multiply; and (2) bettering conditions on the breeding grounds, including elimination of natural enemies and improvement in the supply of the vegetation furnishing cover and food. The Biological Survey is interested in all these efforts and stands ready to give information and assistance to individuals or organizations desiring to carry on such work.

The present report is the first of a series designed to present information on the breeding, wintering, and hunting grounds of waterfowl in the United States. It consists of a report by Dr. Harry C. Oberholser on the water birds, together with data on the numbers and species occurring during the breeding and hunting seasons in Nebraska, chiefly in the sandhill region, which information is a necessary basis for protective legislation; and a report by Mr. W. L. McAtee on the vegetation of 44 lakes of the sandhill region, together with notes on the value of the plants as wild-duck food, and suggestions for improvements.

Part I.—WATERFOWL IN NEBRASKA.

By Harry C. Oberholser, *Assistant Biologist.*

INTRODUCTION.

The principal waterfowl breeding ground in Nebraska is the sandhill region with its numerous lakes. This area has long been famous as a resort for water birds when migrating; consequently, it has offered great inducements as a hunting ground and has attracted thousands of hunters from all parts of the country, some coming from points as far distant as New York and San Francisco. This region not only harbors myriads of ducks during spring and autumn, but is one of the few extensive waterfowl breeding grounds remaining in the United States. In order to determine the numbers and distribution of the waterfowl of Nebraska, the various breeding grounds in Brown, Cherry, Garden, and Morrill Counties were visited by the writer in June, 1915. Practically all the lakes in central and eastern Cherry County were examined, great assistance being rendered by Mr. U. G. Welker, then postmaster at Dewey Lake, himself an experienced hunter; also a large number of the lakes in Garden and Morrill Counties were visited, and careful observations were made of the water birds living on them. At the Orlando Ranch, in the former county, work was greatly facilitated by the open-handed hospitality of Col. S. Avery, its owner. During October of the same year many of the lakes were revisited; a trip was made to the lakes of the North Platte Irrigation Project, near Scotts Bluff; and a careful examination was made of a considerable section of the Platte River between Grand Island and Silver Creek. Much valuable information concerning the sandhill region and its birds was furnished by Dr. Robert H. Wolcott and Prof. Myron H. Swenk, of the University of Nebraska, who also afforded every possible facility for the prosecution of these investigations.

EFFECT OF FEDERAL PROTECTIVE LAWS.

It is the universal testimony of residents and of sportsmen that the myriads of ducks which in former times frequented the sandhill region, particularly during spring and fall, have been greatly reduced. This diminution is due in part to spring shooting, but also to a number of other causes, including the slaughter of ducks in

great numbers both south and north of Nebraska. The migration flights here, however, are still large and show that there remains a good supply of waterfowl, which with proper protection and reasonable regulation of shooting will continue indefinitely to furnish excellent sport. The breeding waterfowl of the sandhills also have suffered from hunters, particularly in spring. On many of the lakes there are clubhouses owned by sportsmen from cities outside of the county, who were long in the habit of shooting here regularly in spring. As a natural consequence, the breeding ducks were seriously interfered with and very greatly reduced in numbers.

The regulations issued by the Department of Agriculture under Federal laws protecting migratory birds have prohibited spring shooting throughout the United States as a necessary means of protecting ducks during the spring migration and the early part of the breeding season. Since the enactment of the Federal statute of 1913, known as the Federal migratory-bird law, there has been comparatively little spring shooting in the sandhill region, for the law seems to have been very well observed. In fact, there seems to be among the inhabitants of the country much sentiment in favor of the abolition of spring shooting, and in this respect no hostility to the Federal law, for many people who live here seem to regard the ducks as undesirable and unfit for food in spring.

In all the localities that the writer visited he made careful inquiries regarding the effect that the stopping of spring shooting has had on the numbers of waterfowl, particularly ducks. It is very gratifying to note that after the Federal law went into effect ducks began steadily to increase in Nebraska, particularly in the lakes of eastern Cherry County, those about the headwaters of the North Loup River, and at the Cody Lakes. As one resident expressed it, as soon as the ducks find out that they will not be disturbed in spring, they come back in increasingly large numbers.

FUTURE OF WATERFOWL IN THE SANDHILL REGION.

In its natural state—that is, unaffected by the presence of man—the sandhill region of Nebraska is an ideal breeding place for waterfowl. It is, indeed, one of the very best of the remaining breeding grounds. The great number of marshy lakes, with their abundant supply of food, shelter, and breeding places, together with the relative absence of enemies, provide advantages which it would be difficult to surpass; and it would be interesting to know the exact conditions here before the advent of the white man. For various reasons the group of lakes in eastern Cherry County and the lakes of Garden and Morrill Counties are at present by far the most important from the standpoint of protection of ducks on their

breeding grounds, although the other groups of lakes already mentioned, as well as many scattered bodies of water throughout the entire sandhill region, form the breeding ground for comparatively large numbers of birds. The settling up of this region opened the lakes to sportsmen, and they have made good use of their opportunity. Other things being equal, water birds do not thrive in thickly settled sections, and with the laying out of the country into farms they have a natural tendency to disappear, owing to the draining of the lakes and the elimination of their breeding grounds, and also to frequent disturbances during the breeding season. Therefore, one can not reasonably expect large numbers of resident ducks in a thickly settled farming region, for their protection becomes more difficult with the increase of population.

In the sandhill region the early settlements were made chiefly by cattlemen, who took large holdings, and not until the Kinkaid law went into effect was there much general addition to the inhabitants. This law permitted the homesteading of an entire section of land after only three years' residence, and resulted in the taking up of practically all the land in this region, as well as in a great increase of population. A continued increase in the population would seriously menace the future of the breeding waterfowl in this region. Only a very small proportion of the land, however, is suitable for farming, but it all is an ideal cattle range, since the sandhills afford good pasture and the hay meadows of the valleys furnish an abundance of winter feed. Thus, not only is the small landholder usually unable to make a living at farming, but his holdings are likewise too small to make stock raising profitable. Consequently, he is sooner or later constrained to sell out and move elsewhere. From this cause title to the land is gradually drifting into the hands of the large landholders, who in a comparatively short time will probably obtain control of the entire area available for grazing in the sandhills. It naturally follows that the population during the past few years has been growing smaller, and will probably still further decrease; and as the land is not so fit for anything as for stock raising, it is not likely that much change in this respect will take place in the future. Thus a possible menace to waterfowl in a great increase of human population is definitely and doubtless permanently removed. Furthermore, there is here practically no danger of the destruction of the grass from overstocking of the grazing ranges.

In some places, however, other difficulties of greater or less moment are arising. At the group of lakes in Brown County, where the character of the soil is considerably better for farming than in other parts of the sandhills, there is apparently a larger permanent popu-

lation, and many of the best lakes lie close to human habitations and are thus easily accessible, which probably will considerably decrease their value as breeding grounds for waterfowl. This is partially substantiated by the fact that in this place comparatively little increase has been apparent in the number of birds since the Federal protective laws went into effect; while in the more remote regions, such as the lakes of eastern Cherry County, the good results from the law have been very marked. Disappearance of marsh vegetation, following the draining of lakes by ditching for the purpose of converting them into hay meadows, also operates to greater or less extent against the protection of waterfowl. A number of lakes have, in this way, been made undesirable for water birds, and these, too, lakes which were particularly attractive to them. In a few cases, however, the water drawn off has formed other lakes which have in a measure made up for the loss. Draining has been practiced most among the lakes at the headwaters of the North Loup River and in Morrill and Garden Counties, but there is apparently no danger that this will be carried to a much greater extent than at present, nor is it likely to be extended to the lakes of eastern Cherry County, the Cody Lakes, or the lakes of Brown County.

NATURAL ENEMIES.

In the Nebraska sandhill region the waterfowl and game birds have relatively few natural enemies. Hawks are not numerous, and those of most frequent occurrence, such as the marsh hawk, the ferruginous rough-legged hawk, and the Krider red-tailed hawk, do little damage to birds. The prairie falcon and the Cooper hawk, which are well-known enemies of birds, are fortunately not common enough in this region to make their presence of serious import. Perhaps the most destructive enemies are the skunk and the coyote, which often destroy eggs in the nest, occasionally kill the adult birds, and not infrequently catch young ducks and other waterfowl. Another drawback to breeding is the frequent hail storms, which kill ducks and other birds on their nests, break the eggs, and destroy young birds.

Man, of course, is the birds' greatest enemy, and were he but absent from the sandhill region, there would be no problem of game protection. It is almost unnecessary to state, however, that if the pursuit of game were to be continued as recklessly and persistently at all times of the year as before the passage of Federal laws protecting migratory birds, the time would not be distant when there would be no birds to shoot; hence, if the game is to be preserved for the future sportsman, as well as for the naturalist, there must be some effective restrictions. With such advantages as the sandhill

region offers there is little difficulty in inducing water birds to breed in numbers almost anywhere, and when they are not disturbed they become exceedingly tame and unsuspicious. On Dewey Lake, in eastern Cherry County, where the writer remained about two weeks, blue-winged teal and coots, apparently unmindful of the presence of human beings, would come regularly, morning and evening, into a little lagoon in the very yard not over 40 or 50 feet from the house, and on more than one occasion a mallard brought her brood of young there. This, as much as anything, shows how quickly the ducks respond to proper encouragement. At the Palmer Ranch, near the head of the North Loup River, the proprietors regularly feed the ducks and other game birds in autumn, on account of which the birds become almost semidomesticated. Among the ranchmen in general there is apparently an increase in sentiment against hunting on their land, which augurs well for the water-bird population, since the small number of birds taken by the local inhabitants does not seriously affect the numbers of even the breeding species. In line with this, it is interesting to note that where the winding trails that answer for roads in much of this country pass through the fences of the ranch pastures the sign "No hunting!" guards many of the gates.

The shooting of ducks in spring while they are migrating and preparing to settle down to the duties of rearing families has two very injurious results. In the first place, if a female be killed, it means not only the loss of that individual bird but of the 8 to 12 young which she would in the course of a month or two add to the waterfowl population. Secondly, the disturbances caused by frequent visits of hunters and the noise of continual discharging of firearms on the breeding grounds greatly annoy the birds and often prevent their breeding in the neighborhood. In fact, spring shooting had practically driven ducks away from some of the best lakes in the sandhill region. Again, shooting too early in autumn is disastrous, for if the hunting season opens before the young ducks are able to take care of themselves they fall ready victims to the gun of the sportsman, or by the death of their parents they are left to shift for themselves before they are able to gain an independent livelihood. In the sandhill region the breeding season is chiefly during May and June, and practically all the ducks are strong on the wing by the first or middle of September; so that present laws, properly enforced, will give sufficient protection at this season.

The protection and preservation of waterfowl as well as other game is not based wholly, as often seems to be the impression, on the ethical grounds of the preservation of the species, and therefore of interest to the naturalist only; it is also a matter of fundamental

concern to the sportsman, who would have no game to shoot were the birds exterminated. The sportsman therefore is vitally interested in game protection, and should be among the first, as in many places he is, to insist on proper protection for the objects of his sport. So far as the sandhill region of Nebraska is concerned, it is evident that comparatively little effort and restraint on his part will produce excellent and desired results. It is necessary to protect the young birds in autumn by enforcing the law until the open season, and it is particularly necessary to preserve the breeding grounds and protect the birds there in spring and during the breeding season. In other words, the prevention of spring shooting is absolutely essential to the preservation of waterfowl in Nebraska; otherwise there will undoubtedly soon be an alarming decrease in the numbers of wild fowl, and possibly even the extermination of many of the species, at least in so far as they may be considered breeding birds of the State. With proper care, however, there should be an abundance of waterfowl for the continued future enjoyment of the sportsman.

HUNTING GROUNDS.

Autumn shooting of waterfowl in Nebraska is of three kinds—lake, pond, and river. Of the first mentioned, the best is to be found in the lake regions of Brown County, eastern Cherry County, central and northern Cherry County, Garden and Morrill Counties, and at various scattered lakes in the central and western portions of the State. Pond shooting, while possible over more or less of the State, is at its best in the region comprising Adams, Clay, and Fillmore Counties, in the southeastern part of the State. River shooting is best on the Platte River between Ashland in the eastern part of the State and North Platte in the west-central section, particularly between Schuyler and Shelton in the eastern portion of the State. Hunting on the Missouri and on some of the smaller streams is of much less importance.

WATERFOWL HUNTING IN THE AUTUMN OF 1915.

Hunting conditions in Nebraska during the autumn of 1915 were somewhat unusual. This was due to at least two causes: the abnormal rainfall throughout the spring, summer, and the greater portion of the autumn; and, secondly, the accompanying mild fall weather, both in Nebraska and in the regions much farther north. The excessive rainfall not only raised the level of most of the larger lakes and filled the streams of the State, but it also greatly increased the number of small temporary lakes and ponds. Thus the ducks found abundant water almost everywhere in the sandhills, as well as in the wet valleys. This resulted in a much more general dis-

persal of the water birds over the country than usual, especially throughout some of the more important groups of lakes. As a consequence the numbers on any particular lake were naturally not proportionately so large as they otherwise would have been, hence hunting was somewhat more difficult. Another result of the great amount of water in the country was the high stage of most of the streams. This furnished, along the creeks and more sluggish small rivers, a much greater attraction for water birds than is ordinarily the case, since every marsh of any extent along such streams was converted into an excellent resort for the birds. On the other hand, the large rivers, like the Platte and the Missouri, were so full of water that the sand bars, which ordinarily form a resting place for waterfowl, were in large part covered, and the ducks were therefore inclined to seek more congenial feeding grounds in the still water of the ponds in the hills.

Under normal conditions, October is the best month for waterfowl hunting in Nebraska, but owing to the mild weather and consequent late season, the October shooting of 1915 was largely confined to the birds which bred in Nebraska or in regions not far to the north. The flight of northern ducks was not fully under way until after the first of November, and as a consequence the northern species, which ordinarily flock about the lakes, ponds, and rivers of the State during the latter part of October, were conspicuous by their absence, or their comparative scarcity. During the first half of November, however, the birds were present in great numbers, apparently much greater than has been usual for the past few years; and, probably owing to the mild weather which prevailed at this time, tarried in the State longer than ordinarily, many until early December.

Notwithstanding the high water and consequent scattering of the ducks and the lateness of the flight of northern birds, hunting during that month of October was, on the whole, unusually good; much better, I am informed, than it had been for a number of years. On almost all the best hunting grounds it was possible for any hunter without unusual exertion to obtain a good bag of ducks, and a failure was the great exception. This satisfactory condition of the hunting is credited by the gunners and residents of the region to the discontinuance of spring shooting, by which has become possible the increase in the number of ducks reared both in Nebraska and farther north. In conversation with numerous hunters and others interested in hunting and the preservation of the game supply, it was noted that with comparatively few exceptions all were very much in favor of the prohibition of spring shooting, for it seems that they are now realizing what this means to the future game supply.

GENERAL DESCRIPTION OF THE SANDHILL REGION.

The sandhill region of Nebraska is an irregular area lying in the north-central part of the State, extending east and west for about 250 miles, north and south for about 140 miles, and occupying approximately one-fourth of the State. There are also isolated areas in southwestern and in extreme western Nebraska, but these are of little importance from our present standpoint. Roughly speaking, the Niobrara River forms the northern boundary of the region, and, except in the eastern half, the Platte is the southern limit. In general, the face of the country is a succession of hills and valleys containing many lakes and occasional running streams. The hills, which are often steep, are mere piles of light-colored sand, for the most part under 200 feet in height and covered with a more or less luxuriant growth of various kinds of grasses. In most places the sand is fine, and, under the high winds which often prevail, is drifted over roads and fences to such an extent that travel is often interfered with and agriculture made difficult. A curious and characteristic feature of the landscape, produced by these high winds, is locally called a "blow-out": it is a miniature crater in the side or top of a sandhill, which has been made by the continual action of the wind on an exposed portion of the slope. In places these "blow-outs" eat into the hills holes 50 or 60 feet deep and 100 feet or more in diameter, but usually they are much smaller. Aside from grass, the vegetation of these sandhills consists chiefly of yuccas (*Yucca glauca*), which in places closely dot the summits and slopes, at a distance giving to the hills a peculiarly spotted appearance. On some of the smaller hills and on the lower slopes of others there are numerous wild-rose bushes (*Rosa pratincola*). The dwarf "sand cherry" (*Prunus besseyi*) and the pale-foliaged amorpha (*Amorpha canescens*) are also abundant all over the hills; while in places there are also great patches of "buck brush" (*Symphoricarpos*). Showy flowers of various kinds, such as lupines, pentstemons, lithospermums, and others, grow in great profusion.

The valleys between the sandhills are sometimes mere hollows, in character not noticeably different from the sandhills themselves; but the larger and deeper valleys are usually more or less level and occupied either by lakes or by meadows, the rank grass of which furnishes excellent hay.

The lakes, which form one of the most interesting features of this region, and which are of supreme importance for the welfare of the waterfowl, occupy many of the larger valleys. These lakes are scattered all over the sandhill region, but by far the greater number lie in a few groups, of which the most important are the following:

(1) Lakes of eastern Cherry County.

(2) Lakes at the head of the North Loup River.

(3) The Cody Lakes.
(4) Lakes of Brown County.
(5) Lakes of Garden and Morrill Counties.

Many of these lakes are more or less ephemeral, though in recent years the area of a number of the larger lakes has grown and the permanency of the smaller ones inclined to become more certain. During unusually rainy seasons the number of temporary ponds is greatly increased, and sometimes these exist even among the sandhills themselves. All these lakes are relatively small, most of them not over three or four miles long, the largest not over seven miles; and they vary from this down to bodies of water of not more than an acre or two, though few of the smallest are permanent. All are relatively shallow, ordinarily not over a few feet in depth, the greatest depth in any being not over 18 or 20 feet. The water of most of them is fresh, or nearly so, but in a few is rather strongly alkaline. Most of the lakes have no outlet except at very high water, and many of them not even then.

With regard to the character of their shores, these lakes may be divided into four categories: (1) those in which the water is wholly or largely covered with vegetation; (2) those with a moderate amount of marsh or other vegetation growing in the water; (3) those with wholly grassy shores but with little or no visible vegetation in the water; and (4) those with sandy shores and with little or no vegetation growing in the water. Of these four the first two are as a rule most favored by ducks, though on some of the lakes of the other two many ducks are sometimes found.

The vegetation of these lakes, aside from the grassy turf which forms the margin of many, consists chiefly of various kinds of sedges, rushes, and coarse grass, growing chiefly in the water; on some there are also more or less extensive areas grown up to wild "cane" (*Phragmites communis*), cat-tails (*Typha latifolia*), and wild rice (*Zizania palustris*), together with yellow waterlilies (*Nymphaea advena*). These and other plants which furnish food for the ducks are dealt with in Part II of this report.

The few perennial streams of the sandhills, chiefly the heads of rivers, flow, except for the marshy valleys at or near their sources, through canyons which they have cut for themselves in the plain. Most of these canyons, however, are narrow and not of great depth. Within the sandhill region proper there is little vegetation along these streams, though at its edge and in the plains country surrounding it the canyons are usually more or less heavily wooded with oaks, pines, elms, junipers, and other similar trees. In fact, about the only trees of any consequence in the sandhills are the cottonwoods that have been planted about the lakes and near ranches.

The mammals of this region are the characteristic species of the Great Plains. On the upland there are numerous coyotes, thirteen-lined ground squirrels, Kennicott ground squirrels, white-tailed jack rabbits, prairie dogs, badgers, pocket gophers, and long-tailed skunks. About some of the rivers and lakes there are still beavers and a good many minks and raccoons, while apparently the most abundant mammal of the lakes is the muskrat, for its houses are to be seen on almost every permanent body of water. The American antelope, which formerly was abundant in this region, is now rare, though occasionally seen.

The birds of the sandhill region, other than the waterfowl which will be separately and specially treated in the present bulletin, though not of a great many species, are yet fairly numerous. Among the land birds the most conspicuous inhabitants of the reeds and rushes in the marshes about the lakes are the red-winged and yellow-headed blackbirds, while an occasional long-billed marsh wren chatters away from his hiding place among the rank vegetation. In the thickets bordering the lakes and some of the streams the Bell vireo, yellow warbler, and Maryland yellowthroat are to be found. The eastern meadowlark is unusually abundant in most of the valley meadows, while the western meadowlark is equally numerous on the higher lands, though both often occur on the same ground. The eastern meadowlark was traced as far west as Phalarope Lake, in northwestern Garden County, where several individuals were seen and heard on June 22, 1915; and the Hague Lakes, just south of Rush Lake, in northeastern Morrill County, where it was noted as common on June 21. The melodious song of the bobolink may be heard throughout the summer in many of the meadows. Prairie chickens and sharp-tailed grouse are common almost everywhere, both in the sandhills and in the grassy valleys; but the bob-white is everywhere rare. The kingbird and the barn swallow are found about almost all the rather scattered ranches of the region, while the orchard oriole and warbling vireo inhabit less regularly the trees and groves in the same places. The grassy sandhills are almost everywhere inhabited commonly by the vesper and grasshopper sparrows, while the lark bunting, conspicuous by its black and white plumage and marvelous mockingbird-like song, may be seen all over the plains and sandhills. Other common birds of general distribution are the mourning dove, the nighthawk, the horned lark, and the cowbird, and in almost every prairie-dog town the curious-mannered burrowing owl.

LAKES OF EASTERN CHERRY COUNTY.

In the central eastern portion of Cherry County lies a group of about 65 lakes covering an area about 35 miles square. In the middle where the lakes are closest together they are in some cases only a

B16350

FIG. 1.—WILLOW LAKE, EASTERN CHERRY COUNTY, NEBR.

Showing sandy character of shore. Many species of ducks frequent this lake.

B16363

FIG. 2.—DADS LAKE, EASTERN CHERRY COUNTY, NEBR.

Showing grassy shore. A breeding ground for the blue-winged teal.

few rods apart, but toward the periphery they are separated sometimes by several miles. From a high point on the southern side of Dewey Lake, 9 or 10 of the largest lakes can be seen, and many more undoubtedly would be within sight but for the high intervening sandhills. These lakes are mostly without outlets, except at very high water; yet, notwithstanding this, only two or three are strongly alkaline, those most so being Big Alkali Lake, Little Alkali Lake, and Alkali Lake. Nearly all are permanent bodies of water, that is, they do not dry up during the summer, except perhaps during exceptionally rainless seasons. They comprise the largest lakes of all the sandhill region, the biggest being Dads Lake, which is about seven miles long and a mile or so in greatest width. Most of these lakes have shores partially grassy or sandy, but have along their borders at least a small amount of marsh; but Clear Lake, Big Lake, White-water Lake, Beaver Lake, Rat Lake, Corneil Lake, Durbin Lake, Coleman Lake, Harold Lake, Cedar Lake, Belsky Lake, and Alkali Lake have so little that it is of no real importance. Big Alkali Lake, Little Alkali Lake, Willow Lake, Dads Lake, Clear Lake, and Muleshoe Lake, together with some others of less importance, have shore lines partly or wholly sandy, although along most of them there is at least a small stretch of marsh. Other lakes of this group which have a greater or less area of marsh are Dewey Lake, Hackberry Lake, Trout Lake, Watts Lake, Chamberlain Lake, Red Deer Lake, Johnson Lake, Foster Lake, Hanna Lake, Pearson Lake, and Pelican Lake. The most important lakes that are wholly or largely covered with vegetation are Ballard Swamp, the valley known as North, Middle, and South Marsh, Wendler Swamp, Molly Marsh, Twenty-one Lake, the Sweetwater Lakes, South School Lake, West Rogers Lake, and Tate Lake.

So far as its breeding water birds are concerned, this group of lakes is the most important in the sandhills, for, with few exceptions, the various kinds of waterfowl are, in summer, more abundant here than anywhere else in the region. Many species, including several kinds of ducks, are very numerous, and some of the lakes present an exceedingly interesting spectacle during the nesting season. The most frequently observed breeding species throughout this group of lakes are, in the order of abundance, the black tern, blue-winged teal, American coot, American eared grebe, shoveller, pintail, mallard, and Wilson phalarope. Well distributed but less numerous are the killdeer, upland plover, and ruddy duck.

This part of Cherry County is a noted resort for hunters, many of whom go regularly every year to enjoy the unusual advantages for sport which the locality affords. Visiting sportsmen have built clubhouses on many of the lakes for their convenience when hunting. The clubhouses now in existence include the following: Red Deer

Club, at the eastern end of Red Deer Lake; Fremont Club, western end of Red Deer Lake; Long Pine Club, eastern end of North Marsh Lake; Johnstown Club, eastern end of Middle Marsh Lake; Council Bluffs Club, southern side of South Marsh Lake; Hackberry Hunting Club, western end of Hackberry Lake; Valentine Hunting Club, northern side of Molly Marsh Lake; Dewey Lake Hunting Club, western end of Dewey Lake; and Wood Lake Hunting Club, northern side of Dewey Lake.

Throughout this part of eastern Cherry County the level of many of the larger lakes was considerably higher in October, 1915, than in the previous June; and there were many additional ponds and smaller lakes scattered throughout the country. As a consequence, several of the large lakes, which under ordinary circumstances have no outlet, were discharging in a stream of considerable volume. This will have a considerable and more or less permanent effect upon the character of the water in these lakes, some of which by isolation had become rather strongly alkaline and thereby less attractive than before to waterfowl. Water birds, particularly ducks, were numerous throughout these lakes, more so than they had been for several years past at this time, notwithstanding the fact that comparatively few northern ducks were present during the time of our visit. There was not so much hunting, apparently, as usual at this time of year, though at many of the lakes parties were out every day.

Observations were conducted in this group of lakes from June 3 to June 18 and from October 5 to October 12, 1915.

WATER BIRDS OBSERVED JUNE 3–18, 1915.

GAME BIRDS.	NONGAME BIRDS.
Hooded merganser.	Horned grebe.
Mallard.	American eared grebe.
Gadwall.	Pied-billed grebe.
Baldpate.	Forster tern.
Green-winged teal.	Black tern.
Blue-winged teal.	American bittern.
Shoveller.	Great blue heron.
Pintail.	Black-crowned night heron.
Redhead.	Wilson phalarope.
Canvas-back.	Spotted sandpiper.
Ring-necked duck.	Killdeer.
Ruddy duck.	
Virginia rail.	
Florida gallinule.	
American coot.	
Western willet.	
Upland plover.	
Long-billed curlew.	

WATER BIRDS OBSERVED OCTOBER 5–12, 1915.

GAME BIRDS.	NONGAME BIRDS.
Hooded merganser.	Horned grebe.
Mallard.	American eared grebe.
Gadwall.	Pied-billed grebe.
Baldpate.	Loon.
Green-winged teal.	Ring-billed gull.
Blue-winged teal.	Franklin gull.
Shoveller.	Forster tern.
Pintail.	American bittern.
Redhead.	Great blue heron.
Canvas-back.	Black-crowned night heron.
Lesser scaup duck.	Killdeer.
Bufflehead.	
Ruddy duck.	
Little brown crane.	
Sandhill crane.	
American coot.	
Wilson snipe.	

LAKES AT THE HEAD OF THE NORTH LOUP RIVER.

The group of lakes at the head of the North Loup River comprises about 20 bodies of water, in general character very similar to those of eastern Cherry County. They lie within an area of 30 miles east and west and about 10 miles north and south; and, with the exception of the westernmost, are relatively close together, most of them from a quarter of a mile to 3 miles apart. The greater number are permanent, though without outlets and therefore more or less alkaline; a few, such as Brush Lake, Mud Lake, and Jumbo Lake, drain into the North Loup River. Nearly all are relatively small, not over a mile or two in length, several of them even less than half a mile long. Silver Lake, Red Willow Lake, White Willow Lake, and Speckelmire Lake, all of which are excellent duck lakes, have little or no marsh about their borders, and some of these, particularly Silver Lake, have partially sandy shores. The Twin Lakes and Mud Lake have a great part of their margins more or less sandy, and are almost deserted by ducks during the summer. Three of the lakes once having the greatest extent of marsh, and therefore furnishing excellent cover for breeding waterfowl, namely, Brush, Scott Pullman, and Jumbo, have been ditched and drained for the purpose of utilizing their valleys as hay meadows. Some of the other lakes, however, have more or less marsh that is attractive to water birds.

Water birds are here fairly plentiful in summer, though on account of the small number of lakes and the draining of some of the best of these, the region is not of so much importance as either the eastern Cherry County group or the lakes of Garden and Morrill

Counties. The most numerous breeding species, in the order of abundance, are the black tern, American eared grebe, American coot, canvas-back, mallard, ruddy duck, blue-winged teal, shoveller, pintail, and gadwall. Other species fairly well distributed but less numerous are the killdeer, Wilson phalarope, and black-crowned night heron. Other kinds are much more poorly represented.

This locality was visited on June 15, 16, and 17, and the complete list of breeding waterfowl observed is as follows:

GAME BIRDS.	NONGAME BIRDS.
Mallard.	American eared grebe.
Gadwall.	Forster tern.
Blue-winged teal.	Black tern.
Shoveller.	American bittern.
Pintail.	Black-crowned night heron.
Redhead.	Wilson phalarope.
Canvas-back.	Killdeer.
Ring-necked duck.	
Ruddy duck.	
American coot.	
Upland plover.	
Long-billed curlew.	

THE CODY LAKES.

There are three lakes a few miles north of the town of Cody, Nebr., and along the boundary line between the States of Nebraska and South Dakota. They are small and permanent, two of them lying about a mile apart and the third, Clear Lake, situated some 6 miles west of the others. North Cody and South Cody Lakes are each about 2 miles long and from one-fourth to one-half a mile wide, while Clear Lake is an irregular oval body of water about a mile in greatest diameter. All have extensive marshes, while South Cody Lake and Clear Lake have also some sandy shore line.

The most abundant of the breeding water birds at these lakes are the black tern, American eared grebe, American coot, killdeer, blue-winged teal, and pintail.

These lakes were visited on June 1, 1915, and the following list of breeding water birds noted:

GAME BIRDS	NONGAME BIRDS.
Mallard.	American eared grebe.
Baldpate.	Pied-billed grebe.
Blue-winged teal.	Forster tern.
Shoveller.	Black tern.
Pintail.	American bittern.
American coot.	Wilson phalarope.
Long-billed curlew.	Killdeer.

LAKES OF BROWN COUNTY.

The lakes of Brown County number about 25, and lie in the southwestern portion. They are scattered over an irregular area about 10 miles east and west and about 14 miles north and south. Moon Lake, the largest of the group, is about 3½ miles long and somewhat more than half a mile wide at its widest point, but most of the others are much smaller, though Enders Lake, including its "overflow," is some 2 miles in length, and Long Lake even more. Moon Lake, one of the northernmost, is separated from the more southern lakes by several miles, but all the others lie much closer together, usually not over a mile apart, and in many cases much less. While few have outlets, none except Alkali Lake are very strongly alkaline. Most of them are permanent, though a few of the smaller ones dry up during the summer. Moon Lake, Willow Lake, Alkali Lake, Crystal Lake, and Long Lake have little or no marsh about their borders, but Filbrick Lake, Marsh Lake, and the "overflow" of Enders Lake are almost entirely surrounded by heavy growths of water vegetation. Most of the others have at least a small area of marsh. Enders, Marsh, Clear, West Chain, Diamond, and Rat Lakes seem to be the best for ducks, while the Twin Lakes, Crystal, Alkali, Long, and Post (or Clapper) Lakes harbor comparatively few. Post Lake and Long Lake are apparently too near human habitations to be successful breeding grounds for waterfowl, and Willow Lake is too much frequented by fishermen. Crystal Lake furnishes no good breeding or feeding ground, but why the Twin Lakes are not inhabited by more water birds is not apparent.

Water birds are fairly well represented in this region during the summer, though much less so than in eastern Cherry County. Perhaps this is partially accounted for by the more thickly settled condition of the country and by the great amount of hunting in years past. The most abundant species of breeding water birds in this area, in their order, are the black tern, American coot, blue-winged teal, American eared grebe, shoveller, mallard, gadwall, black-crowned night heron, and pintail. Others that are fairly well distributed throughout this region, but less numerous, are the killdeer and the upland plover.

As in eastern Cherry County, the exceptional rainfall of the previous few months had, in the autumn of 1915, raised the level of many of the larger lakes, and in some cases converted a more or less temporary pond or marsh into a permanent lake. Water birds in this section were at that time fairly numerous, though ducks were by no means so abundant as in eastern Cherry County, and from all accounts were little, if any, more so than usual. At the time of our

autumn visit, October 10 and 11, we were told that there had been comparatively little hunting in the neighborhood, and that the several clubhouses which are situated on the shore of Enders Lake had not been in use so far during that season. Hunting on some of the lakes with proper blinds was good, and we were told that most of the hunters who had been out had reported fair success.

WATER BIRDS OBSERVED JUNE 13–15, 1915.

GAME BIRDS.	NONGAME BIRDS.
Mallard.	American eared grebe.
Gadwall.	Pied-billed grebe.
Blue-winged teal.	Franklin gull.
Shoveller.	Forster tern.
Pintail.	Black tern.
Redhead.	American bittern.
Canvas-back.	Black-crowned night heron.
Ring-necked duck.	Wilson phalarope.
Ruddy duck.	Killdeer.
American coot.	
Upland plover.	

WATER BIRDS OBSERVED OCTOBER 10–11, 1915.

GAME BIRDS.	NONGAME BIRDS.
Mallard.	American eared grebe.
Gadwall.	Pied-billed grebe.
Baldpate.	Franklin gull.
Green-winged teal.	American bittern.
Blue-winged teal.	Black-crowned night heron.
Shoveller.	Semipalmated sandpiper.
Redhead.	
Canvas-back.	
Lesser scaup duck.	
Ruddy duck.	
Whooping crane.	
American coot.	

LAKES OF GARDEN AND MORRILL COUNTIES.

The group of some 90 or more lakes in the central and western parts of Garden County, and in the eastern part of Morrill County, extends over an area some 30 miles east and west and 25 miles north and south. Most of them are small, usually not over a mile in length, though Swan Lake is 3 or 4 miles long, and both Crescent and Beaver (or Blue) Lakes are about 2 miles long and a mile or more in width. The lakes in this region lie usually close together, and in most places it is difficult to travel for more than a mile or so in any direction without coming upon a lake. Many of them dry up during the hottest part of the summer and during seasons with little rain.

Practically all are without outlets, though only a few, such as Alkali Lake, about 6 miles east of Moffitt, are more or less alkaline. In general character they are typical sandhill lakes. Some, like Rush Lake, which has been mostly drained, Ed Eldred Lake, and Reno Lake, are largely covered with vegetation and, having little open water, are scarcely more than marshes. Others, like Alkali Lake, have practically no marsh, but sandy or marshy shores; yet many of the lakes even of this character possess some area of marsh. A few, like Beaver Lake and Old Lady Lake, with largely grassy or sandy shores, lie almost entirely surrounded by rather steep sandhills. Such lakes are not very attractive to waterfowl, particularly in summer. Swan Lake, which is a noted duck-hunting ground, particularly in the fall, is probably the best-known lake of this region. It is a crooked lake of not more than half a mile or a mile in greatest breadth and consists really of two lakes connected by a narrow passage. It drains eastward through a small lake called Jones Lake, and has comparatively little good marsh except in its eastern and western portions and along its sluggish outlet. It is, however, apparently a fairly good feeding and breeding ground for ducks in summer. Bean Lake, on which is Orlando, is one of the larger lakes of the region, as well as one of the best for ducks, and has a good fringe of marsh around a considerable portion of its shore. The Hague Lakes have been apparently made permanent by the draining into them of the water from Rush Lake, and while they have not extensive areas of marsh, are good places for ducks, even in the summer. Many of the small lakes, like Crosser Lake, Charlie Lake, and Harrison Lake, are excellent breeding grounds for waterfowl, especially during wet seasons, for they have a good fringe of marsh vegetation. This whole area, and particularly its southern portions, is visited in autumn by ducks in countless numbers and is a renowned hunting ground.

Water birds are fairly numerous in summer throughout this group of lakes, and consist of much the same species that frequent the other sandhill waters. The only species of common occurrence not noted elsewhere in the sandhills is the American avocet, which was found at the Hague Lakes, at Wild Goose Lake, Young Lake, Ed Eldred Lake, Swan Lake, Jones Lake, and Alkali Lake on June 21; and near Trainor Lake, near the Peterson Lakes, and at Phalarope Lake on June 22. The most numerous species here, during summer, in the order of abundance, are the American coot, redhead, American eared grebe, shoveller, blue-winged teal, gadwall, Wilson phalarope, black tern, ruddy duck, pintail, and killdeer. Others that are present in much fewer numbers but fairly well distributed are the mallard, American avocet, and black-crowned night heron.

As was the case with the other groups of Nebraska lakes visited during the autumn of 1915, the amount of water in these was considerably greater than usual at that time of the year, and this condition had a corresponding effect on the waterfowl. Birds in this region were, according to reports which we received, more numerous than is common in the autumn, notwithstanding the fact that the northern birds had not yet put in an appearance in any considerable numbers. Hunting was about as good as usual, although considerably more had been done here than in some of the other places we had visited; hence the birds were more unevenly distributed, having taken refuge on certain of the less-frequented bodies of water. There are comparatively few hunting lodges in this region, but the ranch houses serve this purpose for visiting sportsmen.

WATER BIRDS OBSERVED JUNE 21–22, 1915.

GAME BIRDS.	NONGAME BIRDS.
Mallard.	American eared grebe.
Gadwall.	Forster tern.
Blue-winged teal.	American bittern.
Shoveller.	Black-crowned night heron.
Pintail.	Wilson phalarope.
Redhead.	American avocet.
Canvas-back.	Killdeer.
Ruddy duck.	
American coot.	
Western willet.	
Upland plover.	
Long-billed curlew.	

WATER BIRDS OBSERVED OCTOBER 14–15, 1915.

GAME BIRDS.	NONGAME BIRDS.
Mallard.	American eared grebe.
Gadwall.	Pied-billed grebe.
Green-winged teal.	Ring-billed gull.
Blue-winged teal.	American avocet.
Shoveller.	
Pintail.	
Redhead.	
Canvas-back.	
American coot.	

THE PLATTE RIVER.

The Platte River at the time of our visit—October 21–22, 1915—was unusually high for this season, and in many places was running full from bank to bank, covering most of the extensive sand bars and flats that are normally bare. This rendered unavailable much of the

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FIG. 1.—SHIP CREEK, BETWEEN ROUND LAKE AND DUCK LAKE, WESTERN CHERRY COUNTY, NEBR.

A good feeding ground for ducks.

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FIG. 2.—DUCK HUNTERS' CABIN ON THE PLATTE RIVER NEAR GRAND ISLAND, NEBR.

resting grounds for ducks and interfered considerably with river shooting, as most of the ducks had taken refuge back in the hills. A number of hunting parties were seen, however, by whom hunting conditions were reported to be better than usual, even though the northern birds had not yet come down in any considerable numbers. Hunting is carried on here chiefly by building blinds on the small, low islands and sand bars of the river, and there is practically no shooting from the shore. We saw a considerable number of hunting lodges scattered along the river all the way from Grand Island to Schuyler, most of them situated on the banks, but some built on islands that were above the reach of the water even at flood stage. Owing to the conditions above mentioned and to the fact that our visit was cursory and most of it late in the day, comparatively few waterfowl were seen. Even under normal conditions the ducks along the river are best observed early in the morning, since they retire to rest during the later hours of the day; and they do not seem to be as active, except in the morning, as they are about the ponds and lakes. The following birds were noted:

GAME BIRDS.

Mallard.	Shoveller.
Gadwall.	Pintail.
Green-winged teal.	Canada goose.

LAKES OF THE NORTH PLATTE IRRIGATION PROJECT.

The three artificial lakes of the North Platte Irrigation Project have been in existence a comparatively short time, but they are apparently the resting place for some numbers of waterfowl on their migration, and possibly in due time will attract a number of breeding birds. All have grassy shores without rushes or marshes about their borders, and all, particularly Winter Creek Lake, are said to be frequented by ducks in considerable numbers during fall and spring, but very little in summer. Some hunting used to be done here, but, as there is no cover about the lake margins, the ducks are not easily shot. These lakes were visited on October 19, and on this date very few water birds of any kind were seen, it apparently being an unfavorable day for birds on lakes exposed, as are these, to the high wind. Probably at other times the conditions and results would have been more favorable. The only water birds observed were as follows:

GAME BIRDS.

Green-winged teal.	Canvas-back.
Redhead.	Lesser scaup duck.

ANNOTATED LIST OF WATER BIRDS IN THE SANDHILL AND PLATTE RIVER REGIONS OF NEBRASKA.

The following list comprises all the water birds known to breed in the sandhill region of Nebraska. Those not met with by the writer are indicated by a dagger (†). With these are included those observed by the writer during June and October, 1915, in the sandhills and in the Platte River region; and such of these as are not known to breed in the State are indicated by an asterisk (*). The annotations are nearly all from the writer's observations. Autumn notes are placed in separate paragraphs.

Game Birds.

* RED-BREASTED MERGANSER. *Mergus serrator.*

A single female on Pelican Lake, June 10, and another on Big Lake, June 7, both in eastern Cherry County, were the only ones observed.

HOODED MERGANSER. *Lophodytes cucullatus.*

This is one of the rarest summer ducks in the sandhill region, where it frequents chiefly the lakes. The writer's only records are a single bird seen on Dewey Lake, June 12; 2 seen on Dads Lake, June 18; 2 on Mud Lake, in eastern Cherry County, June 8; and 1 on Alkali Lake, in southeastern Cherry County, June 18.

In eastern Cherry County 1 was seen on Red Deer Lake, October 6; 2 shot on Pelican Lake, October 7, and 2 on October 8; 6 seen on Shoveller Lake, October 8; and 11 on White Water Lake, October 12.

MALLARD. *Anas platyrhyncha.*

Though not so abundant as some of the other breeding ducks, the mallard is numerous and well distributed, except in the lakes of Garden and Morrill Counties, where in summer it is much less frequent. It was noted at nearly all the eastern Cherry County lakes and was especially numerous at Dewey Lake, June 3 to 18; Pelican Lake, June 10; Big Lake, June 7; Marsh Lake, June 8; Trout Lake, June 11; Durbin Lake, June 10 and 12; and the easternmost of the Sweetwater Lakes, June 12. Four were noted on South Cody Lake, June 1; and the species was common at most of the Brown County lakes, especially on Enders Lake and Marsh Lake, June 13 and 14. At Speckelmire Lake, near the head of the North Loup River, a flock of 45 was seen on June 16; and the species was observed on the same date at Red Willow Lake, Duck Lake, Round Lake, and Silver Lake of the same group. At the lakes of Garden and Morrill Counties it was less numerous, though fairly well distributed, the largest number (30) being seen on Moffitt Lake, June 21. It was also common on Swan Lake on June 21; Bean Lake, June 21 and 22; Trainor Lake, June 22; and the Peterson Lakes, June 22. This species inhabits both the lakes and the surface ponds, and is one of the best known of all the ducks in this region. A nest containing 9 eggs was seen on June 4 on a high sandhill along the south side of Dewey Lake. This was placed on the ground amid the high grass and yucca plants and was exceedingly well concealed. It afterwards was broken up, however, apparently by a skunk or coyote. Two other

B16341

FIG. 1.—HILL ON SOUTH SIDE OF DEWEY LAKE, EASTERN CHERRY COUNTY, NEBR.

Site of mallard's nest, June 4, 1915.

B16367

FIG. 2.—SANDHILLS COVERED WITH WILD ROSES, SOUTH MARSH LAKE, EASTERN CHERRY COUNTY, NEBR.

A good breeding ground for some species of wild ducks.

nests were found on June 18 in the grass close to the edge of Chamberlain Lake, in southeastern Cherry County, one containing 8, the other 3 eggs. In both cases the female was flushed from the nest. Two broods of 6 and 9 small young, respectively, were seen following their parents at Marsh Lake, in Brown County, June 13; and another brood of 9 young at Enders Lake on the following day. Late in the afternoon of June 14 a female mallard brought its brood of 11 small young into the lagoon close to our house at Dewey Lake and remained there for a considerable time, apparently undisturbed by the presence of several people.

The mallard was also abundant throughout the lake region of eastern Cherry County from October 6 to 9; and at Moon Lake in Brown County, October 10; on October 11, 100 were seen on Twin Lake, 5 at Rat Lake, and 10 on Long Lake, all in Brown County. The species was abundant throughout the lake region of Brown and Morrill Counties, October 14 and 15. Along the Platte River south of Central City two flocks, one of 100 and another of 75, were seen on October 21, and the species was said by hunters to be tolerably common all along the river.

GADWALL. *Chaulelasmus streperus.*

The gadwell is another abundant breeding duck in this region, though in most places not so numerous as the mallard. It was not noted at the Cody Lakes, though it doubtless occurs there, but about the lakes of Garden and Morrill Counties it was in summer many times more abundant than the mallard. It was found most numerous on Pelican Lake, June 10; Dads Lake, June 7 and 10; Belsky Lake, June 12; Muleshoe Lake, June 7; North, Middle, and South Marsh, June 8; Enders Lake, June 13 and 14; Speckelmire Lake, June 16; Moffitt Lake, in Garden County, on June 21; and the three Hague Lakes, in Morrill County, on June 21. It was seen mostly about the margins of the lakes, in small ponds and roadside pools, usually in pairs, but occasionally in small companies.

From October 6 to 9 it was abundant on most of the lakes in the east Cherry County group. Twenty-five were seen on Long Lake, Brown County, October 11; 100 on Peterson's Willow Lake, Garden County, October 14; and 15 on Reno Lake on the same day. It was reported by hunters to be tolerably common on the Platte River from Grand Island to Silver Creek, October 20 to 22.

BALDPATE. *Mareca americana.*

The baldpate is one of the rare ducks, at least in summer. It was noted as follows: three individuals at South Cody Lake on June 1; 3 at Punch Bowl Lake, southwest of Dads Lake, on June 7; 1 at Muleshoe Lake on June 7; and 2 at Hay Lake on June 11.

One was seen on Dewey Lake, eastern Cherry County, October 7, and another on the following day; 3 were noted on West Twin Lake and 5 on south Marsh Lake, Cherry County, October 8. Fifty were observed on Long Lake, Brown County, October 11.

GREEN-WINGED TEAL. *Nettion carolinense.*

This is another rare bird during the breeding season in the Nebraska sandhill region. We observed it at this time only among the lakes of eastern Cherry County. Two were seen at Duck Lake, June 5; 5 on Pelican Lake, June 10; 2 on Molly Marsh, June 11; 2 on Twenty-one Lake, June 12; and 1 at Tate Lake, June 18.

It was abundant everywhere throughout eastern Cherry County, October 6 to 9, 1915; common on several of the lakes in Brown County, October 10 and 11; and abundant everywhere throughout the lakes in Garden and Morrill Counties, October 14 and 15. Seventy-five were seen on Winter Creek Lake, near Scotts Bluff, October 19. The species was said to be very common on the Platte River, October 20 to 22, but we saw none.

BLUE-WINGED TEAL. *Querquedula discors.*

This little duck is one of the best known of all the waterfowl of this region, as is not unnatural from its abundance and wide distribution. It lives wherever there is sufficient water in which to swim—in lakes, large and small, in ephemeral ponds, in ditches, and in roadside pools. It is fond of remaining in the grass, rushes, or reeds about the margins of the lakes, and is not so frequently as some other ducks seen riding the waves out in the wide expanses of open water. In summer it is one of the least suspicious of ducks, and, where not disturbed, may be readily approached. It breeds in numbers throughout the sandhill region, particularly about the lakes of eastern Cherry County, placing its nests on the ground amid the grass, usually not at a great distance from the water. A nest containing 12 eggs was found by the writer on the shore of South Cody Lake on June 1. Others were noted as follows: Three, containing, respectively, 5, 10, and 10 eggs, near the margin of Willow Lake, June 4; one containing 12 eggs, in the grass at Dewey Lake, June 5; one with 11 eggs, at Pelican Lake, June 10; one with 7 eggs, on Molly Marsh, June 11; and one containing 11 eggs near Teal Lake, south of Reno Lake, Garden County, June 22. No broods of young following their parents were seen; so it is fair to assume that these did not begin to appear until about the first of July.

In most places in the sandhills this is, during the breeding season, by far the most abundant and one of the most generally distributed ducks, although in Garden County it is outnumbered by both the redhead and the shoveller. Of the lakes of eastern Cherry County visited in summer it was absent from only three, and from but one of those of Brown County. It was most abundant at Pelican Lake, June 10; Willow Lake, June 4; Dewey Lake, June 3 to 18; Trout Lake, June 11; Red Deer Lake, June 8; Big Lake, June 7; North, Middle, and South Marsh, June 8; Clear Lake, June 4; Big Alkali Lake, June 9; Molly Marsh, June 11, and Muleshoe Lake, June 7. In the other groups of lakes it was less numerous, but still common on South Cody Lake, June 1; Enders Lake, June 13 and 14; Moon Lake, June 13; Marsh Lake, Brown County, June 13 and 14; Diamond Lake, Brown County, June 14; Speckelmire Lake, near the head of the North Loup River, June 16; White Willow Lake, June 16; Red Willow Lake, June 16; the Peterson Lakes, in Garden County, June 22; Reno Lake, June 22; Swan Lake, June 21; Bean Lake, June 21 and 22; Teal Lake, south of Reno Lake, June 22; Phalarope Lake, June 22; and Wild Goose Lake, June 21.

It was tolerably common throughout the lake region of eastern Cherry County, October 6 to 9, and the writer saw 3 at Moon Lake, Brown County, October 10; 3 on Goose Lake, Garden County, October 14; and 3 on Roundup Lake, October 14.

SHOVELLER. *Spatula clypeata.*

One of the best-known ducks in this region, the shoveller is also one of the most beautiful. Like the blue-winged teal, it frequents almost any body of water, however small, and often rises from roadside pools as teams drive along. Though frequently seen out in the open water of the larger lakes, it

remains much of the time along their margins among the vegetation, whence, like the blue-winged teal, it gracefully paddles out into open water when disturbed. Like most of the other ducks, it is fond of sunning itself on the sandy, muddy, or grassy shores of the lakes, and is observable often in considerable companies thus resting. In June it is largely in pairs, though many males are sometimes seen together or singly, the females being probably engaged elsewhere in nesting duties.

Next to the blue-winged teal, the "spoonbill," as this beautiful bird is commonly called, is in summer the most abundant duck throughout almost all of the sandhill region. It is likewise well distributed, as may be inferred from the fact that we saw it at all but six of the lakes in the eastern Cherry County group and at all but three of the Brown County lakes. In the other lake groups it was well-nigh as evenly distributed. Of the lakes in eastern Cherry County it was most abundant at Corneil Lake, June 9; Belsky Lake, June 12; Muleshoe Lake, June 7; North, Middle, and South Marsh, June 8; Pelican Lake, June 10; Clear Lake, June 4; the Sweetwater Lakes, June 12; and Red Deer Lake, June 8. In Brown County most shovellers were seen on Diamond Lake, June 14; Enders Lake, June 13 and 14; Moon Lake, June 13; and Rat Lake, June 14. The species was less numerous about the lakes at the head of the North Loup River, but was common at Speckelmire Lake and in a marsh near White Willow Lake. It was one of the most abundant ducks in Garden County, and was observed most numerously at Moffitt Lake, June 21; the three Hague Lakes, June 21; Phalarope Lake, June 22; Swan Lake, June 21; and Alkali Lake, June 21. It was also noted at South Cody Lake, June 1.

It was abundant on nearly all the lakes in eastern Cherry County, October 6 to 9. Five were seen on Rat Lake, Brown County, October 11, and 50 at Long Lake on the same day. It was abundant on most of the lakes in Garden and Morrill Counties, October 14 and 15; and hunters reported it common on the Platte River, October 20 to 22.

PINTAIL. *Dafila acuta tzitzihoa.*

The pintail is one of the three most numerous breeding ducks of the sandhill region. Found on all the bodies of water, even the roadside pools, it is fond of sitting in the grass by the margins of the lakes with its long neck extended, in which characteristic pose it is readily distinguishable from the other waterfowl. During summer it was not often seen out in the open water of the larger lakes, but seemed to prefer the grassy and reedy marshes and the swamps, as well as the grassy pools. The pintail breeds earlier than the other ducks of this region, and at the time of our visit a large part of the eggs had apparently hatched. We found, however, one nest of nine eggs at Dewey Lake, June 6, and another of seven at Belsky Lake, in eastern Cherry County, June 12. Both were at the edge of the sandhills near the lakes and were mere depressions in the ground lined with down and a little grass. Broods of 1 to 12 small young following their parents were seen on many of the lakes. Nine such family companies were seen on Muleshoe Lake, June 7; and 7 on Pelican Lake, June 10. A brood of 12 was noted on Dewey Lake, June 10, and others on June 5 and 12. Other broods were seen as follows: one on Long Lake, eastern Cherry County, June 5; one at Mallard Lake, June 7; one at Reservoir Lake, June 7; one containing 11 young at Big Lake, June 7; one at Johnson Lake, June 8; and one at Big Alkali Lake, June 9. A brood of 6 young was found with the female on South Cody Lake on June 1; and a brood of 8 young at Long Lake, in Brown County, June 13. The mother bird, when surprised with her young in the water or at the edge of a lake, usually remains in the water and leads the young toward the open lake;

but if at any distance from open water she usually leaves the young to scatter and hide while she attempts to lure away the supposed enemy.

This bird is well distributed over all the groups of lakes visited. It was found most numerous at Pelican Lake on June 10; at Muleshoe Lake, June 7; at Dewey Lake, June 3 to 18; at Smith Lake, June 10; West Twin Lake, June 8; Mallard Lake, June 7; Corneil Lake, June 9; Trout Lake, June 11; and Big Lake, June 7. In fact, it was absent from only eight of the lakes visited in eastern Cherry County and was common at most of the others, including Clear Lake, June 4; Willow Lake, June 4; Dads Lake, June 7; Marsh Lake, June 8; Red Deer Lake, June 8; Ballard Swamp, June 8; L Lake, June 9; Molly Marsh, June 11; the Sweetwater Lakes, June 12; Twenty-one Lake, June 12; and Alkali Lake, June 18. It was also common at the South Cody Lake on June 1; at West Chain Lake, Brown County, June 14; at Moon Lake, June 13; at White Willow Lake, near the source of the North Loup River, June 16; and at Silver Lake, in the same region, June 16. In Morrill County it was common at the Hague Lakes and was noted near Alliance on June 21. In Garden County it was common at Moffitt Lake, June 21; at Silver Lake, June 21; at Bean Lake, June 21 and 22; at Reno Lake, June 22; at the Peterson Lakes, June 22; at Phalarope Lake, June 22; and at Bignell Lake, June 22. We observed it also at several of the other lakes of this region.

On the lakes in eastern Cherry County this duck was common, October 6 to 9; and tolerably common in Garden and Morrill Counties, October 14 to 15. Nine were seen along the Platte River south of Chapman, October 21; and three were seen on the same river south of Silver Creek, October 22. Four shot by hunters near Grand Island, October 20, were seen at a hunting lodge, and the species was reported by hunters to be common.

REDHEAD. *Marila americana.*

This much-hunted duck was seen at the time of our June visit mostly in small flocks and chiefly in the open water of the larger lakes, though also on some of the smaller bodies of water as well. It is one of the ducks that have very greatly increased since the abolition of spring shooting, and it is now very much more numerous as a breeding bird in this region than it was a few years ago. It is common and well distributed during summer in the lakes of eastern Cherry County and of Garden and Morrill Counties, but is much less frequent in other parts of the sandhill region. It is by considerable the most numerous of all the ducks at this season in Garden County and also here more abundant than in any other part of Nebraska. On Bean Lake the writer saw 99 on June 22, and the species was also abundant on the Hague Lakes, June 21; Moffitt Lake, June 21; and common on the Peterson Lakes, June 22; Teal Lake, south of Reno Lake, June 22; Trainor Lake, June 22; Wild Goose Lake, June 21; and Swan Lake, June 21. In eastern Cherry County it was abundant at North, Middle, and South Marsh on June 8; Muleshoe Lake, June 7; Ballard Swamp, June 8; Johnson Lake, June 8, and Dewey Lake, June 3 to 18; also common on Clear Lake, June 4; Red Deer Lake, June 8; Hay Lake, June 8; the Cumbow Lakes, June 11; Foster Lake, June 9; Wendler Swamp, June 10; and Molly Marsh, June 11. It was common on West Chain Lake, in Brown County, June 14; and was noted on Enders Lake, June 14, and on Moon Lake, June 13. Of the lakes at the source of the North Loup River, it was seen only on White Willow Lake, where common, and on Red Willow Lake and Silver Lake, all on June 16. It was not observed on any of the Cody lakes.

Throughout the lake region of eastern Cherry County this duck was common, October 6 to 9. Fifty were seen on Long Lake, Brown County, October 11;

and 500 on Moon Lake, October 10. In Garden and Morrill Counties it was one of the most abundant ducks about the lakes, October 14 and 15; and we saw 100 on Lake Alice, near Scotts Bluff, October 19.

CANVAS-BACK. *Aristonetta valisineria.*

The famous canvas-back duck is fairly common, but of irregular distribution, throughout the sandhill region in summer; and, like the redhead, has very much increased during the past few years. It is most numerous on the lakes at the head of the North Loup River. Here, on June 16, 62 were seen on Silver Lake; 39 on White Willow Lake; and 14 on Red Willow Lake. It was seen, also, at Moon Lake, Brown County, June 13; at West Chain Lake and at Rat Lake, Brown County, June 14. At Trout Lake, in eastern Cherry County, 29 were seen on June 11; and of the other lakes in eastern Cherry County it was noted at Watts Lake, June 5; Little Alkali Lake, June 7; Middle Marsh Lake, June 8; Hay Lake, June 8 and 11; Big Alkali Lake, June 9; Molly Marsh, June 11; Twenty-one Lake, June 12; and Alkali Lake, June 18. In Morrill County a few were seen at the Hague Lakes, June 21, and at Young Lake on the same date. In Garden County it was observed at Moffitt Lake, June 21; Ed Eldred Lake, June 21; Eldred Lake, June 22; and at Trainor Lake on the same date. Like the redhead, this duck occurs most commonly on the larger lakes, where it frequents much the open water, usually in company with other ducks, such as the redhead and ruddy, and with the American eared grebe.

In eastern Cherry County from October 6 to 9, the canvas-back was common on some of the lakes. Two hundred and fifty were seen on South Marsh Lake, October 8, and 500 on Red Deer Lake, October 5. Fifty were observed on Long Lake, Brown County, October 11; 25 on Peterson's Willow Lake, Garden County, October 14, among a much greater number of other ducks, and a flock of 15 was found on Lake Minitare, near Scotts Bluff, October 19.

* LESSER SCAUP DUCK. *Marilæ affinis.*

On June 1, 17 were counted on the open water of South Cody Lake, and 5 on Clear Lake, west of Cody Lake; and on June 5, 7 on Watts Lake, in eastern Cherry County. These seemed to be belated migrants, though it is barely possible that the species occasionally breeds in this region. No others were seen in summer.

Five were seen on Alkali Lake, in eastern Cherry County, October 8; 4 on Dewey Lake, October 12; and 15 on Dads Lake on the same date. Fifty were observed on Long Lake, Brown County, October 11, and 55 on Winter Creek Lake, near Scotts Bluff, October 19.

RING-NECKED DUCK. *Marila collaris.*

The ring-neck is one of the rarer ducks of this region, but we observed it in June at all the groups of lakes, excepting the Cody Lakes and the lakes of Garden and Morrill Counties, and it doubtless occurs there, at least occasionally. It was seen on Wood Lake on May 31; Willow Lake, eastern Cherry County, June 4; Muleshoe Lake, June 7; Mud Lake, June 8; East Twin Lake, eastern Cherry County, June 8; Red Deer Lake, June 8; the Sweetwater Lakes, June 12; Twenty-one Lake, June 12; Alkali Lake, June 18; West Chain Lake, Brown County, June 14; and Red Willow Lake, near the head of the North Loup River, June 16. It was most frequently observed out in the open water, and in pairs or singly, the single birds being chiefly males.

* BUFFLE-HEAD. *Charitonetta albeola.*

One seen on Pelican Lake, October 12, and 3 on Dewey Lake, October 6.

RUDDY DUCK. *Erismatura jamaicensis.*

The ruddy duck was, during summer, one of the interesting sights of the lakes in this region, where it frequented the open water of both ponds and the larger bodies of water, often gathering into companies of considerable size, and regularly associating with other ducks. Its curious habit of sailing about with tail elevated makes it easy to distinguish, even at a considerable distance. Most of the birds seen at this time were either pairs or single males, and such kept more or less separate, even when associated together in a flock of 25 to 50, as was not infrequently the case.

This is one of the common and well-distributed breeding ducks, except in Brown County, where it seems to be rare, and at the Cody Lakes, where we did not see it at all. It was most numerous on Silver Lake, near the head of the North Loup River, June 16; at Dewey Lake, June 3 to 18; Muleshoe Lake, June 7; Red Deer Lake, June 8; Hay Lake, June 8 and 11; Dads Lake, June 7; and East Twin Lake, eastern Cherry County, June 8. It was noted also at Wood Lake, May 31; Clear Lake, June 4; Big Lake, June 7; Marsh Lake, June 8; L Lake, June 9; Big Alkali Lake, June 9; Welker Lake, June 11; Chamberlain Lake, June 18; Pearson Lake, June 18; and at several of the other lakes in eastern Cherry County. Near the head of the North Loup River it was seen on June 16 at Speckelmire, White Willow, and Red Willow Lakes. The only lake in Brown County at which it was observed was Rat Lake, on June 14. In Brown and Morrill Counties it was fairly common at a number of the lakes, particularly Beaver Lake, Swan Lake, Harrison Lake, Ed Eldred Lake, Wild Goose Lake, and the Hague Lakes, all on June 21.

In eastern Cherry County it was common almost everywhere, October 6 to 9. Ten were observed on Moon Lake, in Brown County, on October 10.

CANADA GOOSE. *Branta canadensis canadensis.*

This species, I am credibly told, formerly bred in the sandhill region, but I could get no information that it has done so during the last few years; and it is probably now entirely absent at this season, though, of course, it occurs during the migrations.

A flock of 100 was seen along the Platte River, near Silver Creek, October 22. Hunters told me of shooting one near Grand Island on October 18.

† TRUMPETER SWAN. *Olor buccinator.*

The trumpeter swan was formerly a breeding bird of this region, but, if not now entirely extinct as a species, can no longer be numbered among the summer birds of Nebraska.

WHOOPING CRANE. *Limnogeranus americanus.*

A flock of three was seen flying over Post Lake, Brown County, late in the afternoon of October 10, 1915.

* LITTLE BROWN CRANE. *Grus canadensis canadensis.*

Two were seen five miles east of Red Deer Lake, eastern Cherry County, on October 5, 1915.

SANDHILL CRANE. *Grus canadensis mexicana.*

The sandhill crane formerly reared its young in the sandhills of Nebraska, but probably is not now breeding there.

A flock of 20 was seen near Wood Lake, in eastern Cherry County, October 5, 1915, and four flying over Willow Lake, October 10.

B16384

FIG. 1.—NEST OF COOT (FULICA AMERICANA AMERICANA).

Photograph taken at Pelican Lake, eastern Cherry County, Nebr., on June 10, 1915.

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FIG. 2.—NEST OF PINTAIL (DAFILA ACUTA TZITZIHOA).

Photograph taken at Dewey Lake, eastern Cherry County, Nebr., on June 5, 1915.

† KING RAIL. *Rallus elegans.*

This species has bred at Trout Lake and at some of the other bodies of water in this region, but is apparently rare.

VIRGINIA RAIL. *Rallus virginianus.*

This rail seems to be rare, though known to many inhabitants of the region. We saw it only in eastern Cherry County—two in the marshes bordering Dewey Lake, one at Hackberry Lake, and one at Watts Lake, all on June 5; and two at Big Alkali Lake, June 9.

† SORA. *Porzana carolina.*

The sora is a breeding bird of the lakes, but is apparently everywhere rare.

*** YELLOW RAIL.** *Coturnicops noveboracensis.*

A single bird seen in the marsh on the north shore of Pelican Lake on June 10 was the only individual noted. The lateness of this date indicates that the species may possibly once in a while remain to breed in the sandhill country.

FLORIDA GALLINULE. *Gallinula chloropus cachinnans.*

This is apparently a rare bird here. We found it only at Hackberry Lake, eastern Cherry County, where we saw two on June 5, 1915.

AMERICAN COOT. *Fulica americana americana.*

This species was found in summer at all the lakes, both large and small, wherever there was a sufficient growth of rushes, reeds, or other vegetation about the shores to offer opportunity for concealment and for nesting. It was breeding numerously during June. Of 4 nests found on Pelican Lake, June 10, the only one examined contained 6 eggs. On West Cumbow Lake, which has very little open water, but is largely marsh and of limited extent, we noted 8 nests on June 11; and on Welker Lake, which has still less suitable vegetation, we noted 4 nests on the same date. At the third Sweetwater Lake, on June 12, we found, without special search, 11 nests, one of which contained 10 eggs. Undoubtedly careful search would reveal hundreds of nests of this species on the lakes of this region. Although June seems to be its chief breeding season, this species apparently begins to nest in early May, as indicated by a brood of five small young seen on Hackberry Lake, eastern Cherry County, June 5. Considering the value of its flesh as food, it is rather surprising that so much prejudice exists against this bird as an object of sport.

Next to the black tern, this well-known bird, commonly called mud-hen, is in summer the most numerous of all the kinds of waterfowl in the sandhill region, and on some of the small lakes almost incredibly numerous. On Pearson Lake 179 were counted on June 18; and on Marsh Lake, Brown County, a lake barely three-quarters of a mile long, 89 were counted on June 13. Other lakes on which it was very abundant are Red Deer Lake, June 8; Pelican Lake, June 10; the third Sweetwater Lake, June 12; Lee Lake, June 18; Hackberry Lake, June 5; Dewey Lake, June 3 to 18; Willow Lake, June 4, all in eastern Cherry County; Speckelmire Lake, June 16; White Willow Lake, June 16; Red Willow Lake, June 16; Silver Lake, June 16, all at the head of the North Loup River; Eldred Lake, June 22; Swan Lake, June 21; and the Peterson Lakes, June 22, all in Garden County.

About the lakes in eastern Cherry County this bird was the most abundant species of waterfowl from October 6 to 9, 1915, and we noted it at practically all the lakes. Nineteen hundred were observed at Pelican Lake, alone, on October 12. Likewise, on the lakes of Brown County, October 10 to 11, it was

by far the most abundant water bird, and was seen on nearly all the lakes visited. On Enders Lake 2,500 were noted, October 11. On most of the lakes of Garden and Morrill Counties it was also abundant, October 14 to 15.

WILSON SNIPE. *Gallinago delicata.*

This well-known game bird was common throughout eastern Cherry County in most of the wet valleys and in the vicinity of the lakes, October 6 to 9, 1915.

*** LESSER YELLOW-LEGS.** *Totanus flavipes.*

Seven were seen at South Cody Lake on June 1; 3 on the upper part of Gordon Creek a few miles north of Simeon, June 3; and one on Hackberry Lake, eastern Cherry County, June 5. No others were noted.

WESTERN WILLET. *Catoptrophorus semipalmatus inornatus.*

This noisy shore bird is tolerably common during summer in the lake region of eastern Cherry County and of Morrill and Garden Counties, but we did not observe it elsewhere. We saw it on Willow Lake, eastern Cherry County, June 4; Pelican Lake, June 5; Mallard Lake, June 7; Dads Lake, June 7; Muleshoe Lake, June 7; West Twin Lake, June 8; Ballard Swamp, June 8; Johnson Lake, June 8; Trout Lake, June 11; Big Alkali Lake, June 9; and, of the lakes in Garden County, Moffitt Lake, June 21; Eldred Lake, June 22; Alkali Lake, June 21; Bean Lake, June 21; and Teal Lake, June 22. It was noted almost always singly or in pairs about the marshes, meadows, or the margins of the lakes.

UPLAND PLOVER. *Bartramia longicauda.*

The upland plover is, during summer, a tolerably common and fairly well-distributed bird in the sandhill region, though nowhere abundant. It is most numerous in eastern Cherry County, where we saw it about many of the lakes, including Dewey Lake, June 3 to 18; Hackberry Lake, June 5; Pelican Lake, June 10; Muleshoe Lake, June 7; Big Lake, June 7; Red Deer Lake, June 8; Trout Lake, June 11; Corneil Lake, June 9; Big Alkali Lake, June 9; Wendler Swamp, June 10; the Sweetwater Lakes, June 12; Twenty-one Lake, June 12; and Chamberlain Lake, June 18. In Brown County it was noted at Post Lake, June 13; Filbrick Lake, June 13; Enders Lake, June 14; Marsh Lake, June 13; Long Lake, June 14; Alkali Lake, June 14; and Rat Lake, June 14. Near the source of the Loup it was noted only near White Willow Lake and at Brush Lake, both on June 16. In Garden County it was seen at Reno Lake, June 22; Teal Lake, June 22; and near Trainor Lake, June 22. It was not seen at all about the Cody Lakes.

This species in summer frequents chiefly the meadows and marshes about the lakes and in the moist valleys, being entirely absent from the drier parts of the sandhills. So far as we observed its habits, its name "upland" plover is a misnomer in this region, for it seemed greatly to prefer the wet ground and frequently waded in the waters of the marshes near the margins of the lakes. According to the testimony of residents it is much less numerous than formerly.

LONG-BILLED CURLEW. *Numenius americanus americanus.*

Though formerly abundant in the sandhill region, the long-billed curlew is at present apparently uncommon during summer. We observed it as follows: one at Long Lake, eastern Cherry County, June 17; 1 at Pelican Lake, June 10; 1 at Little Alkali Lake, June 17; 4 at Dads Lake, June 7; 4 at Reservoir Lake, west of Dads Lake, June 7; 3 at Punch Bowl Lake, southwest of Dads

Lake, June 7; 1 at White Willow Lake, near the source of the North Loup River, June 16; 3 on the Hague Lakes, in Morrill County, June 21; and 1 on Jones Lake, east of Swan Lake, Garden County, June 21. This bird was seen both in the hills in the vicinity of the lakes and along the shores near the water.

Nongame Birds.

† WESTERN GREBE. *Aechmophorus occidentalis.*

The western grebe was found nesting at Island Lake, Garden County, in June, 1916.

HORNED GREBE. *Colymbus auritus.*

This grebe, during summer, is apparently very rare in the sandhill region, as the writer saw but a single individual in June, this in a small pond close to Corneil Lake, north of Big Alkali Lake, on June 9, 1915.

One was seen on Clear Lake, eastern Cherry County, October 9, 1915.

AMERICAN EARED GREBE. *Colymbus nigricollis californicus.*

The American eared grebe, so far as we observed it, stayed principally in the open water, though of course at times among the rushes, and apparently is fond of swimming about and diving far out in the middle of the lakes. Its habit of holding the neck and crest erect makes it easy to distinguish even at a distance.

This is one of the most abundant of the summer water birds in the region, and breeds on many of the lakes. The writer counted 349 on Dads Lake on June 7, 305 of them in a single company. On White Willow Lake, near the head of the North Loup River, 186 were seen on June 16. It was abundant on Dewey Lake from June 3 to 18; Willow Lake, June 4 to 14; Trout Lake, June 9 and 11; at Wendler Swamp, June 10 and 18; Pearson Lake, June 18; and Speckelmire Lake, June 16. It was common on Silver Lake, June 16; Rat Lake, Brown County, June 14; West Chain Lake, Brown County, June 14; Johnson Lake, June 8; West Twin Lake, eastern Cherry County, June 8; the Hague Lakes, eastern Morrill County, June 21; Bean Lake, June 21 and 22; and the Peterson Lakes, Garden County, June 22. It was rather generally distributed throughout the lakes of Garden, Morrill, and Brown Counties, but somewhat more irregularly in the other localities.

A single individual was noted on Red Deer Lake, eastern Cherry County, October 6; 2 on Moon Lake, Brown County, October 10; and 1 on Goose Lake, Garden County, October 14.

PIED-BILLED GREBE. *Podilymbus podiceps podiceps.*

Unlike the preceding species, this grebe did not frequent much the open water, but kept for the most part within the protection of the reeds and rushes bordering the lakes. At the eastern end of Dewey Lake on June 4, a nest in the rushes near the shore, from which a female was seen to depart, was found to contain 8 eggs. It finally came to grief in a heavy windstorm which a few days later swept the lake.

This bird of retiring habits is apparently not very common. I did not see it at all during June in Morrill County, nor in any of the lakes about the source of the North Loup River. Two were seen at Marsh Lake, Brown County, June 13; 1 on Welker Lake, June 11; 1 at Wendler Swamp, June 10; 4 on Johnson Lake, June 8; 1 on Red Deer Lake, June 8; 1 on West Twin Lake, eastern Cherry County, June 8; 3 on Long Lake, eastern Cherry County, June 5; 1 on Watts Lake, June 5; 2 on Hackberry Lake, June 5; 4 on Willow Lake, June 4; and 3 on South Cody Lake, June 1.

In autumn, in eastern Cherry County, it was seen as follows: one on Middle Lake, October 8; 12 on Clear Lake, October 9; 1 on Dewey Lake, October 12; and 1 on Whitewater Lake, October 12. In Brown County one was seen on Moon Lake, October 10; 1 on Filbrick Lake on the same date; and 2 on Enders Lake, October 11. In Garden County 2 were found on Goose Lake, October 14, and 1 on Roundup Lake on the same day.

* LOON. *Gavia immer.*

A single individual was observed on Pelican Lake, eastern Cherry County, October 12, 1915.

* FRANKLIN GULL. *Larus franklinii.*

This species was seen in summer on only three occasions: One at Duck Lake, eastern Cherry County, June 5; 4 on Enders Lake, Brown County, June 13; and 4 at Clear Lake, Brown County, June 14.

A single individual was seen at Shoveller Lake, eastern Cherry County, October 8; and 6 on Twin Lake, Brown County, October 11.

* RING-BILLED GULL. *Larus delawarensis.*

A flock of 11 was seen on the south shore of Dewey Lake on June 4, and a solitary individual was noticed flying along the lake on the previous day; 4 were noticed on Clear Lake, June 3, and 3 on the following day, but all these may have been derived from the flock seen on Dewey Lake. No others were noted in summer on any of the lakes.

On most of the lakes in eastern Cherry County this gull was common, October 6 to 9, 1915; and we saw one on Blue Lake, Garden County, October 14, and 7 on Crescent Lake on the same day.

FORSTER TERN. *Sterna forsteri.*

The loud, harsh cries and dazzling white plumage of the Forster tern make it a conspicuous object as it beats about over the lakes. It is fond of perching on fence posts or stakes in the water, but descends to the ground not so frequently as the black tern.

This tern is common in summer throughout the region visited, except about the lakes at the head of the North Loup River and the lakes of Garden and Morrill Counties. It is most numerous and generally distributed on the lakes of eastern Cherry County, and there most abundant on Pelican Lake, where the writer saw 40 on June 10. It was common at Dewey Lake from June 3 to 18. We saw 6 on Clear Lake, June 4; 8 on Hackberry Lake, June 5; 6 on Red Deer Lake, June 8; 5 on Trout Lake, June 11; 11 on Big Alkali Lake, June 9; and 4 on Molly Marsh, June 11. It was noted also at Watts Lake on June 5; Wendler Swamp on June 10; at the easternmost of the Sweetwater Lakes, June 12; on South Cody Lake, June 1; on Clear Lake, Brown County, June 14; Willow Lake, Brown County, June 14; and West Twin Lake, near the head of the North Loup River, June 16. It was abundant at Moon Lake, Brown County, where 24 were seen on June 13. The only lakes in Garden County at which this tern was noted were Jones Lake, where 4 were seen, and Beaver Lake, where 7 were observed, all on June 21.

Five were seen on Dewey Lake, eastern Cherry County, on October 7, and 2 others on Pelican Lake, October 12, 1915.

* COMMON TERN. *Sterna hirundo.*

A single individual at Dewey Lake on June 5 was the only individual noted.

BLACK TERN. *Hydrochelidon nigra surinamensis.*

This is by far the most abundant summer water bird throughout all this region, except about the lakes of Garden and Morrill Counties, and outnumbers by more than two to one any of the other waterfowl. It is also one of the most generally distributed. It may be seen often in large companies—flocks they could hardly be called, for they are usually spread out all over the lakes on which they occur. The largest number of black terns seen at any one place was at Trout Lake, where 532 were counted on June 9 and 11. They were very abundant also on South Cody Lake, June 21; Dewey Lake, June 3 to 18; Pelican Lake, June 10; Dads Lake, June 7; Marsh Lake, June 8; Hay Lake, June 8 and 11; Wendler Swamp, June 10 and 18; Pearson Lake, June 18; Enders Lake, June 13 and 14; West Chain Lake, Brown County, June 14; Silver Lake, near the head of the North Loup River, June 16; and common on Moffitt Lake, Garden County, June 21; and on Bean Lake, June 21 and 22. The crackling cry and the hovering, butterflylike flight of this dainty little species are sure to attract attention. It may be seen often resting on the exposed sand bars or mud flats about the lakes or on heaps of vegetation among the rushes. It breeds in numbers on many of the lakes.

AMERICAN BITTERN. *Botaurus lentiginosus.*

This bird is rather common in summer about the lakes, though apparently not numerous in any locality. It was seen on Gordon Creek, near Simeon, June 3; at Watts Lake, June 5; Pelican Lake, June 10; Marsh Lake, June 8; Red Deer Lake, June 8; Foster Lake, June 9; L Lake, June 9; Whitewater Lake, June 10; Molly Marsh, June 11, all in eastern Cherry County; Diamond Lake, Brown County, June 14; Speckelmire Lake, at the head of the North Loup River, June 16; West Twin Lake, at the head of the North Loup River, June 16; Jones Lake, Garden County, June 21; Beaver Lake, June 21; Bean Lake, June 21; and Teal Lake, June 22.

In eastern Cherry County, one was noted on Dewey Lake, October 5, another on October 7, and three on October 12. One was seen on Marsh Lake, October 8; six on Pelican Lake, October 12; and one on Moon Lake, in Brown County, on October 10.

† LEAST BITTERN. *Ixobrychus exilis.*

This species occurs occasionally in summer in the marshes about the lakes in the sandhill region, but is apparently nowhere common.

GREAT BLUE HERON. *Ardea herodias herodias.*

Of rare occurrence in most of the sandhill country, but known to breed. We saw only two individuals in summer—one at Willow Lake, eastern Cherry County, June 4, 1915; the other at Thedford, on the Loup River, June 19.

Two were seen near Red Deer Lake, eastern Cherry County, on October 5, and one on Dewey Lake, October 12.

BLACK-CROWNED NIGHT HERON. *Nycticorax nycticorax naevius.*

This is a common summer bird over the greater part of the sandhill region, though of somewhat irregular distribution. It was seen at all the groups of lakes excepting the Cody Lakes, but was most numerous at Pelican Lake on June 10, when 105 were seen. It was also numerous at Moon Lake, Brown County, on June 13, and White Willow Lake, near the source of the North Loup River, on June 16. In small numbers it was observed on Dewey Lake, June 4; Willow Lake, June 4; Marsh Lake, June 8; Big Alkali Lake, June 9;

Smith Lake, June 10; Whitewater Lake, June 10; Molly Marsh, June 11, all in eastern Cherry County; Post (Clapper) Lake, Brown County, June 13; Red Willow Lake, June 16; Swan Lake, Garden County, June 21; Jones Lake, Garden County, June 21; and on several of the other lakes throughout the sandhills. It occurred in summer chiefly about the lakes, where it frequented usually the marshes about their borders. Occasionally it was in flocks of considerable size, as on Pelican Lake and on Moon Lake, as above noted.

In eastern Cherry County, 3 were seen between Wood Lake and Dewey Lake on October 5; 1 on Red Deer Lake, October 6; 10 on Dewey Lake, October 12, and others at different times on this lake; and 1 on Moon Lake, Brown County, October 10.

WILSON PHALAROPE. *Steganopus tricolor.*

The dainty appearance and ducklike habits of this little wader at once attract the attention of even the casual observer. In Garden County it goes by the name "straw." It frequents chiefly the meadows and marshes about the lakes, though it often alights out on the water itself, particularly near the shore. Occasionally it appears along the streams, especially those that have marshy borders.

This is by considerable the most numerous breeding shore bird in the sandhill country, though it is not quite so universally distributed as the killdeer. It was, however, found commonly or abundantly at all the groups of lakes visited, being most abundant at Phalarope Lake, Garden County, June 22; Pelican Lake, eastern Cherry County, June 10; Ballard Swamp, June 8; North and Middle Marsh, June 8; Foster Lake, June 9; Belsky Lake, June 12; and Trout Lake, June 9 and 11. It was common also at South Cody Lake, June 1; Dewey Lake, June 3 to 18; Long Lake, eastern Cherry County, June 5; Dads Lake, June 7; Muleshoe Lake, June 7; Big Lake, June 7; Red Deer Lake, June 8; Big Alkali Lake, June 9; Smith Lake, June 10; Sweetwater Lakes, June 12; Middle Lake, June 12; Duck Lake, near the head of the North Loup River, June 16; the Hague Lakes, Morrill County, June 21; Alkali Lake, Garden County, June 21; and at many of the other lakes of the region.

AMERICAN AVOCET. *Recurvirostra americana.*

The avocet, though formerly occurring over all the sandhill region, was not observed, except at the lakes of Garden and Morrill Counties. Here it was tolerably common in summer, though irregularly distributed. We noted it as follows: the Hague Lakes, June 21; Wild Goose Lake, June 21; Young Lake, June 21; Moffitt Lake, June 21; Swan Lake, June 21; Jones Lake, June 21; Alkali Lake, June 21; a small lake near Trainor Lake, June 22; a small lake near the Peterson Lakes, June 22; and Phalarope Lake, June 22.

One was seen at Reno Lake, Garden County, October 14, 1915.

* WHITE-RUMPED SANDPIPER. *Pisobia fuscicollis.*

One, on Gordon Creek a few miles north of Simeon, on June 3, was the only individual observed.

* BAIRD SANDPIPER. *Pisobia bairdii.*

Two were seen along the shore of Coleman Lake, eastern Cherry County, on June 10, but the species was not otherwise noted.

* LEAST SANDPIPER. *Pisobia minutilla minutilla.*

A single bird seen on the upper part of Gordon Creek a few miles north of Simeon, June 3, is the only record.

*** SEMIPALMATED SANDPIPER.** *Ereunetes pusillus.*

A flock of 20 was seen at Crystal Lake, in Brown County, on October 11, 1915.

† MARBLED GODWIT. *Limosa fedoa.*

This species is reported to have been found breeding here, but it is apparently very rare at this season.

† SOLITARY SANDPIPER. *Helodromas solitarius solitarius.*

Reported to be a breeding bird of the sandhill region, but seemingly very rare; we did not observe it at any of the localities visited.

SPOTTED SANDPIPER. *Actitis macularia.*

The well-known spotted sandpiper is apparently rare in this region, as we saw only four individuals, all on the upper part of Gordon Creek a few miles north of Simeon, June 3.

KILLDEER. *Oxyechus vociferus vociferus.*

This ubiquitous species is, of course, one of the most widely distributed summer shorebirds of the region. At this season it was found at or near a great majority of the lakes, and in some places was abundant. It was most numerous in eastern Cherry County, on Willow Lake, June 4 to 14; Dewey Lake, June 3 to 18; Pelican Lake, June 10; Trout Lake, June 11; Big Alkali Lake, June 9; Dads Lake, June 7; Hackberry Lake, June 5; Gordon Creek, June 3; Ballard Swamp, June 8; and North, Middle, and South Marsh, June 8. It was common also at South Cody Lake on June 9; Moon Lake, Brown County, June 13; Enders Lake, June 13 and 14; Rat and Diamond Lakes, Brown County, June 14; Speckelmire Lake, near the source of the North Loup River, June 16, and at Silver Lake in the same region on the same date; also at Reno Lake, Garden County, June 22; Eldred Lake, June 22; Bean Lake, June 21 and 22; the Peterson Lakes, June 22; and at the Hague Lakes, in Morrill County, June 21. Young were seen with their parents at Ballard Swamp on June 8 and on several occasions during June at other localities.

Our only autumn record is a single bird seen at Ballard Swamp, eastern Cherry County, October 7, 1915.

† PIPING PLOVER. *Charadrius melodus.*

This plover was formerly apparently not uncommon about the lakes of the sandhill region, and formerly bred about Trout Lake, eastern Cherry County. We, however, did not observe a single individual at any of the localities visited.

Part II.—WILD-DUCK FOODS OF THE SANDHILL REGION OF NEBRASKA.

By W. L. McAtee, *Assistant Biologist.*

INTRODUCTION.

The sandhill region of Nebraska is one of a myriad of ponds and lakes. Not only are bodies of water very plentiful and comparatively little visited by man, but also they are well supplied with the vegetation which furnishes the cover so necessary to breeding wild ducks as well as a large proportion of their food. It is not surprising, therefore, that this region is a paradise for wild fowl.

The wild-duck foods and other vegetation growing in and about 44 lakes of the sandhill region are the subject of the present report, which is based on notes and specimens collected during the period from July to October, 1915, by Mr. Ray Thomson, then a graduate student of the University of Nebraska. The specimens were identified by the writer, with the following assistance in difficult groups: Grasses, Prof. A. S. Hitchcock and Mrs. Agnes Chase; *Carex*, Mr. G. P. Van Eseltine; *Juncus*, Mr. Frederick V. Coville; and Compositæ, Mr. Paul C. Standley. Two species of aquatic mosses were kindly identified by Miss Mary Miller, and a willow by Mr. C. R. Ball.

Most of the lakes visited by Mr. Thomson are well supplied with plants valuable as food for wild ducks, and this is especially true of Dewey, Hackberry, Beaver, White Willow, Marsh, and Cody Lakes, and Ballard Swamp, Cherry County; and Gimlet Lake, Garden County. It is worthy of note that sago pondweed (*Potamogeton pectinatus*), probably the best all-around duck food, was found in every lake visited except Trout Lake, Cherry County, and there is little doubt that the plant grows in that lake also. Wild rice (*Zizania*), an excellent wild-duck food, was found in four of the Brown County lakes, in eight of those of eastern Cherry County, and in the Cody Lakes, but was not found in any of the lakes at the head of the Loup River nor in those of Garden County.

The most important wild-duck foods in addition to sago pondweed and wild rice that occur generally in the sandhill region are:

Musk grass (*Chara* spp.).
Small pondweed (*Potamogeton pusillus*).
Variable pondweed (*Potamogeton heterophyllus*).
Bushy pondweed (*Najas flexilis*).
Wapato (*Sagittaria latifolia*).
Wild millet (*Echinochloa crus-galli*).
Big bulrush (*Scirpus occidentalis*).
River bulrush (*Scirpus fluviatilis*).
Tule (*Scirpus validus*).
Big duckweed (*Spirodela polyrhiza*).
Small duckweed (*Lemna minor*).
Star duckweed (*Lemna trisulca*).
Coontail (*Ceratophyllum demersum*).

So far as food conditions are concerned, therefore, the lakes of the sandhill region of Nebraska are well fitted to be a wild-duck breeding-ground of the first rank.

IMPROVEMENT OF WILD-DUCK FOOD SUPPLY.

The most notable deficiency in the above list of plants is wild celery (*Vallisneria spiralis*). This is an excellent duck food and undoubtedly will grow in practically all the lakes of the sandhill region. It probably will grow anywhere that sago pondweed does. Chufa (*Cyperus esculentus*) also was not found among the plants collected, although it is especially suited to growth in sandy soil. It may be used to advantage as a duck food only where there are areas dry in summer, to permit growth of the plant, and flooded in winter, so that the ground may be softened sufficiently for ducks to dig the tubers.

However, as noted above, most of the lakes of the sandhill region are well provided with wild-duck foods. In few cases is need of improvement indicated, and the only agencies practically interested in improving the food supply of ducks are shooting clubs controlling certain bodies of water. To them it may be said that adding wild celery or chufas to bodies of water where conditions are suitable, or any of the plants in the preceding list where they do not now exist, will improve the feeding conditions for wild fowl. Directions for propagating most of these plants are contained in Bulletins of the United States Department of Agriculture, Nos. 205 and 465.[1] Further information relating to the plants and the names of dealers in them will be furnished by the Biological Survey upon request.

EFFECT OF ALKALINE CONDITIONS ON DUCK-FOOD PLANTS.

The most important information gained in the study of the duck-food plants of the sandhill region relates to the comparative tolerance of the different species to alkalinity of the water. According to Dr. R. J. Pool, "the waters of practically all of the many ponds and lakes contain considerable quantities of saline and alkaline compounds."[2] This being the case, and in view of the luxuriant growth of aquatic plants in most of the lakes, it is evident that the degree or quality of alkalinity of most of them is not injurious.

The lakes examined during the present investigation that are popularly recognized as alkaline are Rat and Willow Lakes in Brown County; Big Alkali, Clear, and Silver Lakes in Cherry County, and, to a lesser degree, Red Willow, White Willow, and Speckelmire Lakes of the same county; and Moffitt, Crescent, Beaver (or Blue), Phalarope, and Peterson Lakes in Garden County.

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[1] Eleven important wild-duck foods, Bull. 205, U. S. Dept. Agr., pp. 25, figs. 23, May 20, 1915; Propagation of wild-duck foods, Bull. 465, pp. 40, figs. 35, Feb. 23, 1917.

[2] A study of the vegetation of the sandhills of Nebraska. Minn. Botanical Studies, vol. 4, Part III, p. 275, 1914.

Those in which unfavorable conditions are reflected in the character of the vegetation are Big Alkali and Silver, and to a lesser extent Clear Lake, and all the Garden County lakes; the others have the usual abundant aquatic growth. In addition to these the collector notes that Twenty-one Lake, Cherry County, is perhaps a little alkaline; however, this is not evident in the vegetation. From the character of the plant growth one would judge that Jones and Swan Lakes, also of Garden County, are alkaline.

The lesser injurious effects of alkalinity upon submerged vegetation are largely reduction of the quantity of such growth and unthriftiness of the species not adapted to withstand alkaline condition. The effect of still further concentration of alkalis in the water is elimination of most of the species of submerged aquatic plants, and the almost exclusive occupation of the water by certain resistant species. Concentration beyond this point undoubtedly would have a disastrous effect upon even these hardy species, but this condition was not observed in any of the 44 lakes examined.

Probably the most severe alkaline conditions of any of these lakes are represented by Peterson Lake No. 2, Garden County. In this lake widgeon grass (*Ruppia occidentalis*),[1] a plant that grows in brackish water, is the dominant submerged species, practically filling the lake. Sago pondweed is the only other subaqueous growth. In the other lakes in which aquatic plants are greatly affected by alkalinity, sago pondweed in every case is the dominant and often the only submerged growth. It is fortunate that such plants as these endure the most alkaline waters of the sandhills, because both are very important wild-duck foods, especially the sago. This pondweed also thrives in brackish water, which fact, together with the occurrence of the widgeon grass, suggests that the same qualities that adapt plants for growth in salt water enable them to resist the injurious effects of alkalis. This idea is further borne out by the character of the semisubmerged plants associated with the two species above named in their alkaline habitat. These include saltgrass (*Distichlis spicata*) and three-square (*Scirpus americanus*), both of which grow in coastal salt marshes. Another salt-marsh plant, namely, arrow-grass (*Triglochin maritima*), while occurring at several places in the sandhills, seems to have no special relation to alkaline conditions.

The species ranking next in their endurance of alkalinity, though by no means to be compared with the above, are curly pondweed (*Potamogeton perfoliatus richardsonii*), small pondweed (*Potamogeton pusillus*), and spike rush (*Eleocharis*, probably *glaucescens*). Wild rice can not endure salt, nor, presumably therefore, alkalis.

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[1] This species was collected in Reno Lake also.

This probably explains its absence from Loup River and the Garden County lakes.

In attempting to stock alkaline waters with wild-duck foods, therefore, it will be best to center efforts upon establishing widgeon grass or sago pondweed. Wild celery withstands salt as well as these two plants and probably would equal them in alkali resistance, though this has not been tried out. A purely theoretical suggestion is that eelgrass (*Zostera marina*), an inhabitant of ocean-water, might be found adapted to stronger alkaline waters than any of these three plants.

LIST OF PLANTS OF THE SANDHILL LAKES.

The descriptions of lakes given in the following pages, the classification of the plants according to their place of growth, and notes on abundance are taken in the main from the reports of Mr. Ray Thomson. He is responsible, therefore, for the bulk of the occurrence records. These are based on a system of "collector numbers" which he used in making his reports, and were translated into plant names after the specimens were identified in Washington. Where specimens from any locality were actually examined an asterisk (*) follows the name of the species. Remarks other than those on abundance, and a few other obvious field observations, are based on specimens.

Each list is followed by a paragraph commenting on the value of its components as food for wild ducks.

LIST OF LAKES VISITED, WITH DATES, 1915.

Brown County

Enders Lake—Aug. 10, 14 (p. 41).
Enders Lake Overflow—Aug. 11 (p. 42).
Marsh Lake—Aug. 12, 13 (p. 43).
Rat Lake—Aug. 14 (p. 44).
Willow Lake—Aug. 15 (?) (p. 44).
West Chain Lake—Aug. 16 (p. 45).
Middle Chain Lake—Aug. 16 (p. 46).

Cherry County (Eastern Part).

Dewey Lake—Aug. 21–24 (p. 46).
Willow Lake—Aug. 23, 24 (p. 48).
Clear Lake—Aug. 25 (p. 49).
Hackberry Lake—Aug. 27 (p. 50).
Watts Lake—Aug. 29 (p. 51).
Trout Lake—Aug. 31 (p. 52).
Pelican Lake—Sept. 1 (p. 53).
Rat Lake—Sept. 3, 4 (p. 54).
Beaver Lake—Sept. 3, 4 (p. 55).
Wendler Swamp—Sept. 4, 10 (p. 55).
Sweetwater Lakes—Sept. 6 (p. 56).
Twenty-one Lake—Sept. 6 (p. 57).
Marsh Lakes—Sept. 7 (p. 58).
Red Deer Lake—Sept. 10 (p. 59).
Ballard Swamp—Sept. 10 (p. 59).
Big Alkali Lake—Sept. 13 (p. 60).
Molly Marsh—Sept. 13 (p. 61).
Hay Lake—Sept. 14 (p. 62).

Cherry County (Northern Part).

South Cody Lake—Sept. 18–19 (p. 62).
North Cody Lake—Sept. 20 (p. 64).

Cherry County (Headwaters Loup River).

Red Willow Lake_____Oct. 9 (p. 65).
White Willow Lake____Oct. 10 (p. 66).
Specklemire Lake_____Oct. 12 (p. 67).
Yearling Valley Lake__Oct. 13 (p. 67).
Silver Lake_____Oct. 17 (p. 68).

Garden County.

Moffitt Lake_____Sept. 23 (p. 69).
Gimlet Lake_____Sept. 24 (p. 70).
Crescent Lake_____Sept. 26 (p. 71).
Beaver (or Blue) Lake____Sept. 27–28 (p. 71).
Jones Lake_____Sept. 27–28 (p. 72).
Swan Lake_____Sept. 27–28 (p. 73).
Reno Lake_____Sept. 29 (p. 74).
Trainor Lakes_____Sept. 30 (p. 75).
Peterson Lake, No. 1____Oct. 2 (p. 75).
Peterson Lake, No. 2____Oct. 2 (p. 76).
Phalarope Lake_____Oct. 3 (p. 77).

ENDERS LAKE, BROWN COUNTY.

August 10 and 14, 1915.

Description.—Little or no marsh. Rich growth of submerged vegetation. Fresh water, average greatest depth 6 feet; bottom in general mucky, sandy at southeast end. No inlet; outlet into Enders Lake Overflow.

Distribution of Vegetation.

SHORE PLANTS.

Narrow zone of wet meadow on east and south shores containing a typical mixture of wet meadow plants. Among those growing next to water line were:

1. Cord-grass (*Spartina michauxiana*). Common.
2. Switchgrass (*Panicum virgatum*). Common.
3. Hair-grass (*Agrostis hyemalis*).
4. Redtop (*Agrostis alba*).
5. Bog reedgrass (*Calamagrostis inexpansa*). Common.
6. Reed canary-grass (*Phalaris arundinacea*).
7. Wild rye (*Elymus canadensis*).* Flowers.
8. Sedge (*Carex vulpinoidea*).
9. Shining sedge (*Cyperus rivularis*).* Common.
10. Water hemlock (*Cicuta maculata*). Not abundant.
11. Marsh mint (*Stachys palustris*).
12. Mint (*Mentha canadensis*).* Flowers.
13. Ragweed (*Ambrosia elatior*).* Abundant; flowers.

SEMISUBMERGED PLANTS.

14. Wapato, or arrowhead (*Sagittaria latifolia*).* Common; flowers.
15. Crested wapato (*Sagittaria cristata*).* Flowers to immature fruit.
16. Big bulrush (*Scirpus occidentalis*).* Abundant; flowers.
17. Spike rush (*Eleocharis acicularis*).*

SUBMERGED PLANTS.

Dominants:

19. Waterweed (*Philotria canadensis*).* Flowers.
20. Water milfoil (*Myriophyllum spicatum*).* Immature fruit.

Principal species:

21. Sago pondweed (*Potamogeton pectinatus*).* Flowers to mature fruit.
22. Curly pondweed (*Potamogeton perfoliatus richardsonii*).* Flowers to mature fruit.

Secondary species:

23. Eelgrass pondweed (*Potamogeton compressus*).* Immature fruit.
24. Small pondweed (*Potamogeton pusillus*).* Mature fruit.
25. Floating pondweed (*Potamogeton natans*).* Mature fruit.

FLOATING PLANTS.

26. Star duckweed (*Lemna trisulca*).
27. Big duckweed (*Spirodela polyrhiza*).

Wild-duck foods.—Plants in the above list which have considerable value as food for ducks are Nos. 14, 16, 21, 24, 26, and 27; those of lesser importance are: Nos. 1, 2, 6, 8, 9, 17, 19, 20, 22, 23, and 25; the remainder are of no known value.

ENDERS LAKE OVERFLOW, BROWN COUNTY.

August 11, 1915.

Description.—Very little marsh. Semisubmerged vegetation abundant. Water fresh; small amount open; depth 6 to 7 feet. No outlet; inlet from Enders Lake.

Distribution of Vegetation.

SHORE PLANTS.

Wide zone of wet meadow.

1. Cord-grass (*Spartina michauxiana*). Common.
2. Switchgrass (*Panicum virgatum*). Common.
3. Hair-grass (*Agrostis hyemalis*).
4. Redtop (*Agrostis alba*).
5. Bog reedgrass (*Calamagrostis inexpansa*).*
6. Shining sedge (*Cyperus rivularis*). Common.
7. Straw sedge (*Cyperus strigosus*). Abundant.
8. Sedge (*Carex vulpinoidea*).
9. Rush (*Juncus nodosus*). Abundant.
10. Rush (*Juncus canadensis*). Common.
11. Water hemlock (*Cicuta maculata*).
12. Marsh mint (*Stachys palustris*).

SEMISUBMERGED PLANTS.

Dominants:

13. Spike rush (*Eleocharis acuminata*).* Flowers.
14. Water smartweed (*Polygonum amphibium*).* Flowers.

Secondary species:

15. Bur reed (*Sparganium eurycarpum*).* Immature fruit.
16. Wapato (*Sagittaria latifolia*).
17. Reed (*Phragmites communis*).*
18. Big bulrush (*Scirpus occidentalis*).

SUBMERGED PLANTS.

Dominants:

19. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
20. Floating pondweed (*Potamogeton natans*).

Secondary species:

21. Water moss (*Drepanocladus aduncus aquaticus*).
22. Sago pondweed (*Potamogeton pectinatus*).
23. Eelgrass pondweed (*Potamogeton compressus*).
24. Small pondweed (*Potamogeton pusillus*).
25. Variable pondweed (*Potamogeton heterophyllus*).*
26. Water milfoil (*Myriophyllum spicatum*).

FLOATING PLANTS.

27. Star duckweed (*Lemna trisulca*).
28. Big duckweed (*Spirodela polyrhiza*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 16, 18, 22, 24, 25, 27, and 28; those of lesser importance are: Nos. 1, 2, 6, 7, 8, 14, 15, 19, 20, 23, and 26; the remainder are of no known value.

MARSH LAKE, BROWN COUNTY.

August 12–13, 1915.

Description.—Fresh-water lake, well filled with vegetation. Little open water, average greatest depth 6 to 7 feet, bottom mucky except at east end. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

A mixture in which no species are dominant is found in a narrow zone of wet meadow (2 to 5 rods) except on east side.

1. Cord-grass (*Spartina michauxiana*).* Flowers.
2. Switchgrass (*Panicum virgatum*).*
3. Hair-grass (*Agrostis hyemalis*).*
4. Redtop (*Agrostis alba*).*
5. Bog reedgrass (*Calamagrostis inexpansa*).*
6. Couch-grass (*Agropyron repens*).
7. Reed canary-grass (*Phalaris arundinacea*).*
8. Straw sedge (*Cyperus strigosus*).* Mature fruit.
9. Shining sedge (*Cyperus rivularis*).* Immature fruit.
10. Three-way sedge (*Dulichium arundinaceum*).* Flowers.
11. Sedge (*Carex vulpinoidea*).* Mature fruit.
12. Sedge (*Carex scoparia*).* Mature fruit.
13. Rush (*Juncus nodosus*).*
14. Rush (*Juncus canadensis*).* Abundant; flowers to immature fruit.
15. Rush (*Juncus marginatus*).* Mature fruit.
16. Rush (*Juncus dudleyi*).* Capsules empty.
17. Water hemlock (*Cicuta maculata*).* Flowers.
18. Marsh mint (*Stachys palustris*).* Flowers.
19. Water marigold (*Bidens beckii*).*

SEMISUBMERGED PLANTS.

Dominants:

20. Big bulrush (*Scirpus occidentalis*).
21. Spikerush (*Eleocharis acuminata*).
22. Water smartweed (*Polygonum amphibium*).

Secondary species:

23. Western water plantain (*Alisma brevipes*).* Flowers to immature fruit.
24. Wapato (*Sagittaria latifolia*).
25. Crested wapato (*Sagittaria cristata*).
26. Reed (*Phragmites communis*).
27. Rush (*Juncus balticus*).* Flowers.

SUBMERGED PLANTS.

Dominants:

28. Curly pondweed (*Potamogeton perfoliatus richardsonii*).

Secondary species:

29. Sago pondweed (*Potamogeton pectinatus*).*
30. Eelgrass pondweed (*Potamogeton compressus*).
31. Small pondweed (*Potamogeton pusillus*).* Flowers.
32. Floating pondweed (*Potamogeton natans*).
33. White water crowfoot (*Batrachium circinatum*).*
34. Bladderwort (*Utricularia vulgaris*).*
35. Water milfoil (*Myriophyllum spicatum*).

FLOATING PLANT.

36. Star duckweed (*Lemna trisulca*).*

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 20, 24, 29, 31, and 36; those of lesser importance are: Nos. 1, 2, 8, 9, 11, 12, 19, 21, 22, 28, 30, 32, 33, and 34; the remainder are of no known value.

RAT LAKE, BROWN COUNTY.

August 14, 1915.

Description.—No marsh, and grazed to water's edge around entire lake. Largely open water; average greatest depth 3 to 4 feet; bottom sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Not conspicuous.

1. Wild millet (*Echinochloa crus-galli*).* Mature fruit.
2. Sedge (*Carex nebraskensis*).* Mature fruit.
3. Rush (*Juncus nodosus*).*
4. Richweed (*Pilea pumila*).*
5. Yellow monkey-flower (*Mimulus geyeri*).*
6. Mint (*Mentha canadensis*).

SEMISUBMERGED PLANTS.

Dominants:

7. Wild rice (*Zizania palustris*).* Flowers.
8. Big bulrush (*Scirpus occidentalis*).

Secondary species:

9. Cat-tail (*Typha latifolia*).
10. Western water plantain (*Alisma brevipes*).* Not common.
11. Geyer water plantain (*Alisma geyeri*).* Immature fruit.
12. Wapato (*Sagittaria latifolia*).* Immature fruit.
13. Crested wapato (*Sagittaria cristata*).

SUBMERGED PLANTS.

Dominants:

14. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
15. Water milfoil (*Myriophyllum spicatum*).*

Secondary species:

16. Musk grass (*Chara* sp.)*
17. Sago pondweed (*Potamogeton pectinatus*).
18. Long-leaved pondweed (*Potamogeton americanus*).* Flower buds.
19. Bushy pondweed (*Najas flexilis*).* Immature fruit.
20. Coontail (*Ceratophyllum demersum*). Abundant.

FLOATING PLANTS.

21. Star duckweed (*Lemna trisulca*).*
22. Big duckweed (*Spirodela polyrhiza*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 7, 8, 12, 16, 17, 19, 20, 21, and 22; those of lesser importance are: Nos. 2, 10, 11, 13, 14, 15, and 18; the remainder are of no known value.

WILLOW LAKE, BROWN COUNTY.

August 15 (?), 1915.

Description.—No marsh area. Water clouded, owing to abundance of a single-celled alga; mostly open water; average greatest depth 6 feet; bottom, as a whole, sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Include principally:

1. Cord-grass (*Spartina michauxiana*).
2. Wild millet (*Echinochloa crus-galli*).
3. Switchgrass (*Panicum virgatum*).
4. Redtop (*Agrostis alba*).

SEMISUBMERGED PLANTS.

Dominants:
5. Wapato (*Sagittaria latifolia*).
6. Spike rush (*Eleocharis acuminata*).

Secondary species:
7. Reed (*Phragmites communis*).
8. Wild rice (*Zizania palustris*). Rare.
9. Big bulrush (*Scirpus occidentalis*).

SUBMERGED PLANTS.

Dominants:
10. Sago pondweed (*Potamogeton pectinatus*).
11. Water milfoil (*Myriophyllum spicatum*).

Secondary species:
12. Eelgrass pondweed (*Potamogeton compressus*).
13. Floating pondweed (*Potamogeton natans*).
14. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
15. Small pondweed (*Potamogeton pusillus*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2, 5, 8, 9, 10, and 15; those of lesser importance are: Nos. 1, 3, 11, 12, 13, and 14; the remainder are of no known value.

WEST CHAIN LAKE, BROWN COUNTY.

August 16, 1915.

Description.—Little or no marsh area. Well filled with vegetation. Bottom mucky; depth 4 feet. No inlet; outlet during high water into Middle Chain Lake.

Distribution of Vegetation.

SHORE PLANTS.

About as for neighboring lakes.

1. Switchgrass (*Panicum virgatum*).
2. Wild rye (*Elymus canadensis*).
3. Indian grass (*Sorgastrum nutans*).* Flowers.
4. Redtop (*Agrostis alba*).

SEMISUBMERGED PLANTS.

Dominants:
5. Cat-tail (*Typha latifolia*).* Mature fruit.
6. Crested wapato (*Sagittaria cristata*).
7. Big bulrush (*Scirpus occidentalis*).

Secondary species:
8. Wild rice (*Zizania palustris*). Very scattered stand on east end.
9. Spike rush (*Eleocharis acuminata*).
10. Water smartweed (*Polygonum amphibium*).* Flowers.

SUBMERGED PLANTS.

Dominants:
11. Waterweed (*Philotria canadensis*).
12. Water milfoil (*Myriophyllum spicatum*).

Secondary species:
13. Sago pondweed (*Potamogeton pectinatus*).* Mature fruit.
14. Variable pondweed (*Potamogeton heterophyllus*).* Flowers.
15. Floating pondweed (*Potamogeton natans*).
16. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
17. Long-leaved pondweed (*Potamogeton americanus*).*
18. Bushy pondweed (*Najas flexilis*).
19. Coontail (*Ceratophyllum demersum*).*

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 7, 8, 13, 14, 18, and 19; those of less importance are: Nos. 1, 6, 10, 11, 12, 15, 16, and 17; the remainder are of no known value.

MIDDLE CHAIN LAKE, BROWN COUNTY.

August 16, 1915.

Description.—Marsh at east end. Bog at west end, which is inaccessible. Lake entirely filled with vegetation. Bottom mucky; greatest depth, 4 feet; inlet from West Chain Lake during high water; outlet into East Chain Lake.

Distribution of Vegetation.

SHORE PLANTS.

1. Cord-grass (*Spartina michauxiana*).
2. Switchgrass (*Panicum virgatum*).
3. Redtop (*Agrostis alba*).
4. Couch-grass (*Agropyron repens*).
5. Wild millet (*Echinochloa crus-galli*). Common.
6. Wild rye (*Elymus canadensis*). Common.
7. Indian grass (*Sorghastrum nutans*).
8. Shining sedge (*Cyperus rivularis*).
9. Straw sedge (*Cyperus strigosus*).
10. Sedge (*Carex scoparia*).
11. Sedge (*Carex nebraskensis*).
12. Rush (*Juncus nodosus*).
13. Rush (*Juncus marginatus*).
14. Rush (*Juncus dudleyi*).
15. Water hemlock (*Cicuta maculata*).

SEMISUBMERGED PLANTS.

Dominants:
16. Wapato (*Sagittaria latifolia*).
17. Big bulrush (*Scirpus occidentalis*).

Secondary species:
18. Bur reed (*Sparganium eurycarpum*).
19. Cat-tail (*Typha latifolia*).
20. Spike rush (*Eleocharis acuminata*).
21. River bulrush (*Scirpus fluviatilis*).* Abundant; mature fruit.
22. Reed (*Phragmites communis*).
23. Wild rice (*Zizania palustris*). Very little.
24. Water smartweed (*Polygonum amphibium*).

SUBMERGED PLANTS.

Dominants:
25. Waterweed (*Philotria canadensis*).
26. Coontail (*Ceratophyllum demersum*).

Secondary species:
27. Sago pondweed (*Potamogeton pectinatus*).
28. Eelgrass pondweed (*Potamogeton compressus*).
29. Floating pondweed (*Potamogeton natans*).
30. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
31. Small pondweed (*Potamogeton pusillus*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 5, 16, 17, 23, 26, 27, and 31; those of less importance are: Nos. 1, 2, 8, 9, 10, 11, 18, 21, 24, 25, 28, 29, and 30; the remainder are of no known value.

Notes on Other Brown County Lakes.

There are about 20 acres of wild rice (*Zizania palustris*) at the west end of Long Lake, and about 20 to 30 acres at Frank Wales Swamp, between Long Lake and Clopper Lake. Filbrick Lake is said to contain a considerable area of rice.

DEWEY LAKE, CHERRY COUNTY.

August 21–24, 1915.

Description.—Extensive marsh area at west end of the lake. Mostly open water; depth 9 to 10 feet; bottom mostly sandy except at west end and extreme east end, which is muck. Outlet into Willow Lake; inlet from White Water Lake; this inflow from White Water Lake during high water has probably rendered Dewey Lake somewhat alkaline.

Distribution of Vegetation.

SHORE PLANTS.

1. Cord-grass (*Spartina michauxiana*).* Common: flowers.
2. Switchgrass (*Panicum virgatum*).* Abundant.
3. Bog reedgrass (*Calamagrostis inexpansa*).* Common.
4. Satin grass (*Muhlenbergia foliosa*).* Common; flowers.
5. Straw sedge (*Cyperus strigosus*).* Common.
6. Spike rush (*Eleocharis acicularis*).* Common on wet shore and shallow water; flowers.
7. Sedge (*Carex scoparia*).* Rare; flowers.
8. Rush (*Juncus balticus*).*
9. Rush (*Juncus torreyi*).* Common; flowers.
10. Rush (*Juncus marginatus*).* Abundant; mature fruit.
11. Rush (*Juncus dudleyi*).* Common; mature fruit.
12. Richweed (*Pilea pumila*).* Common; immature fruit.
13. Heart's-ease (*Polygonum pennsylvanicum*).*
14. Water-hemp (*Acnida tuberculata*).* Common; flowers.
15. Dragon-head (*Dracocephalum virginianum*).* Common.
16. Mint (*Mentha canadensis*).* Common; flower buds.
17. Marsh mint (*Stachys palustris*).* Common.
18. Willow herb (*Epilobium lineare*).* Sparse; flowers to mature fruit.
19. Small cleavers (*Galium trifidum*).* Sparse in marsh and wet shore; flowers to immature fruit.
20. Blue lobelia (*Lobelia syphilitica*).* Common; flowers.
21. Sticktight (*Bidens trichosperma*).* Sparse; flowers.

MARSH, OR BOG, PLANTS.

22. Marsh fern (*Dryopteris thelypteris*).* Common.
23. Bur reed (*Sparganium eurycarpum*). Sparse.
24. Wapato (*Sagittaria latifolia*). Abundant.
25. Reed (*Phragmites communis*). Abundant.
26. Spike rush (*Eleocharis acuminata*).
27. Spike rush (*Eleocharis acicularis*).* Common; flowers.
28. Big bulrush (*Scirpus occidentalis*). Abundant.
29. Sedge (*Carex utriculata*).* Common; mature fruit.
30. Tall dock (*Rumex altissimus*).* Sparse; immature fruit.
31. Water hemlock (*Cicuta maculata*).* Sparse; flowers.

SEMISUBMERGED PLANTS.

Dominants:

32. Reed (*Phragmites communis*).* Flowers.
33. Big bulrush (*Scirpus occidentalis*).* Flowers.

Secondary species:

34. Bur reed (*Sparganium eurycarpum*).* Sparse; immature fruit.
35. Cat-tail (*Typha latifolia*).
36. Wapato (*Sagittaria latifolia*).* Abundant; flowers to immature fruit.
37. Arrow-grass (*Triglochin maritima*).* Common; flowers.
38. Wild rice (*Zizania palustris*). Sparse at west end of lake and in poor condition.
39. Spike rush (*Eleocharis acuminata*).* Flowers.
40. Water smartweed (*Polygonum amphibium*).* Common; mature fruit.

SUBMERGED PLANTS.

Dominants:

41. Water moss (*Drepcnocladus aduncus aquaticus*).
42. Coontail (*Ceratophyllum demersum*).*

Secondary species:

43. Eelgrass pondweed (*Potamogeton compressus*).* Common.
44. Sago pondweed (*Potamogeton pectinatus*).* Common.
45. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
46. Illinois pondweed (*Potamogeton illinoensis*). Sparse.
47. Bushy pondweed (*Najas flexilis*).* Common.
48. Small pondweed (*Potamogeton pusillus*).* Common.
49. Water smartweed (*Polygonum amphibium*). Sparse.
50. Spatterdock (*Nymphaea advena*).* Common; flowers to mature fruit.
51. Water milfoil (*Myriophyllum spicatum*).* Common.
52. Bladderwort (*Utricularia vulgaris*).* Common.

FLOATING PLANTS.

53. Star duckweed (*Lemna trisulca*).* Common.
54. Small duckweed (*Lemna minor*).* Common.
55. Big duckweed (*Spirodela polyrhiza*).* Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 24 (36), 28 (33), 38, 42, 44, 47, 48, 53, 54, and 55; those of less importance are: Nos. 1, 2, 5, 6, 7, 13, 21, 23, 26 (39), 29, 34, 40 (49), 43, 45, 46, 50, and 51; the remainder are of no known value.

WILLOW LAKE, CHERRY COUNTY.

August 23–24, 1915.

Description.—Little or no marsh; grazed to water's margin on north, east, and south shores. Well filled with vegetation. Open water extensive, average greatest depth 9 feet. Inlet from Dewey Lake; outlet into Trout Lake.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as for Dewey Lake.

MARSH PLANTS.

Small amount at west side.

1. Cord-grass (*Spartina michauxiana*).
2. Straw sedge (*Cyperus strigosus*). Abundant.
3. Spike rush (*Eleocharis acuminata*).
4. Spike rush (*Eleocharis acicularis*). Common.
5. Big bulrush (*Scirpus occidentalis*).
6. Rush (*Juncus balticus*). Common.
7. Rush (*Juncus torreyi*). Common.
8. Dragon-head (*Dracocephalum virginianum*).
9. Marsh mint (*Stachys palustris*).

SEMISUBMERGED PLANTS.

Dominant:
10. Big bulrush (*Scirpus occidentalis*).*

Secondary species:
11. Wapato (*Sagittaria latifolia*).
12. Spike rush (*Eleocharis acuminata*). Common.
13. Water smartweed (*Polygonum amphibium*). Common.

SUBMERGED PLANTS.

Dominant:
14. Water milfoil (*Myriophyllum spicatum*).*

Secondary species:
15. Sago pondweed (*Potamogeton pectinatus*). Common.
16. Eelgrass pondweed (*Potamogeton compressus*).* Common; nearly mature fruit; winter buds.
17. Small pondweed (*Potamogeton pusillus*).* Common; immature fruit.
18. Bushy pondweed (*Najas flexilis*). Common.
19. Water smartweed (*Polygonum amphibium*). Sparse.
20. White water crowfoot (*Batrachium divaricatum*).* Common; flowers.
21. Coontail (*Ceratophyllum demersum*). Common.

FLOATING PLANT.

22. Star duckweed (*Lemna trisulca*).* Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 5 (10), 11, 15, 17, 18, 21, and 22; those of less importance are: Nos. 1, 2, 3 (12), 4, 13 (19), 14, and 16; the remainder are of no known value.

CLEAR LAKE, CHERRY COUNTY.

August 25, 1915.

Description.—Some marsh at east end; narrow zone of wet meadow along south shore. Largely open water; average greatest depth, 7 to 8 feet; bottom at east and west ends mucky, while the other portion is sandy. No inlet; overflow into Willow Lake, during high water.

Distribution of Vegetation.

SHORE PLANTS.

1. Bur reed (*Sparganium eurycarpum*). Sparse.
2. Arrow-grass (*Triglochin maritima*). Common on wet shore.
3. Cord-grass (*Spartina michauxiana*). Sparse.
4. Switchgrass (*Panicum virgatum*). Common.
5. Hairy crabgrass (*Panicum huachucae*).* Common; immature and mature fruit.
6. Saltgrass (*Distichlis spicata*).* Abundant; mature fruit.
7. Squirrel-tail (*Hordeum jubatum*).* Abundant.
8. Broom-grass (*Andropogon furcatus*).* Common.
9. Dropseed (*Sporobolus asperifolius*).* Sparse.
10. Bog reedgrass (*Calamagrostis inexpansa*). Common.
11. Straw sedge (*Cyperus strigosus*). Common.
12. Spike rush (*Eleocharis acicularis*). Common on wet shore.
13. Sedge (*Carex scoparia*).
14. Rush (*Juncus balticus*).* Common on wet shore.
15. Rush (*Juncus dudleyi*). Common.
16. Rush (*Juncus marginatus*).
17. Bushy knotweed (*Polygonum ramosissimum*).* Common.
18. Heart's-ease (*Polygonum pennsylvanicum*).
19. Richweed (*Pilea pumila*).
20. Dragon-head (*Dracocephalum virginianum*).
21. Marsh mint (*Stachys palustris*).
22. Mint (*Mentha canadensis*).

MARSH PLANTS.

Consisting largely of:

23. Big bulrush (*Scirpus occidentalis*).*

Others are:

24. Squirrel-tail (*Hordeum jubatum*).
25. Saltgrass (*Distichlis spicata*).
26. Bushy knotweed (*Polygonum ramosissimum*).*

SEMISUBMERGED PLANTS.

Dominants:

27. Spike rush (*Eleocharis acuminata*).
28. Big bulrush (*Scirpus occidentalis*).

Secondary species:

29. Wapato (*Sagittaria latifolia*). Sparse.
30. Reed (*Phragmites communis*). Sparse.

SUBMERGED PLANTS.

Submerged vegetation is scattered and not abundant.

Dominant:

31. Sago pondweed (*Potamogeton pectinatus*).

Secondary species:

32. Eelgrass pondweed (*Potamogeton compressus*). Common.
33. Small pondweed (*Potamogeton pusillus*). Common.
34. Illinois pondweed (*Potamogeton illinoensis*). Not abundant.
35. Bushy pondweed (*Najas flexilis*). Sparse.
36. Coontail (*Ceratophyllum demersum*). Sparse.
37. Water milfoil (*Myriophyllum spicatum*. Sparse.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 23 (28), 29, 31, 33, 35, and 36; those of less importance are: Nos. 1, 2, 3, 4, 6 (25), 11, 12, 13, 18, 27, 32, 34, and 37; the remainder are of no known value.

HACKBERRY LAKE, CHERRY COUNTY.

August 27, 1915.

Description.—Lake well filled with submerged vegetation. Open water extensive; average greatest depth, 5 to 6 feet; bottom mostly mucky. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

1. Cord-grass (*Spartina michauxiana*). Sparse.
2. Switchgrass (*Panicum virgatum*). Abundant.
3. Bog reedgrass (*Calamagrostis inexpansa*). Common.
4. Satin grass (*Muhlenbergia foliosa*). Common.
5. Straw sedge (*Cyperus strigosus*). Abundant.
6. Spike rush (*Eleocharis acicularis*). Common on wet shore and shallow water.
7. Sedge (*Carex scoparia*).
8. Rush (*Juncus torreyi*). Common.
9. Rush (*Juncus marginatus*).
10. Richweed (*Pilea pumila*). Common.
11. Heart's-ease (*Polygonum pennsylvanicum*). Common.
12. Bushy knotweed (*Polygonum ramosissimum*).*
13. Water-hemp (*Acnida tuberculata*). Sparse.
14. Dragon-head (*Dracocephalum virginianum*). Common.
15. Marsh mint (*Stachys palustris*).
16. Blue lobelia (*Lobelia syphilitica*). Sparse.
17. Burweed (*Iva xanthifolia*).* Common; flowers.
18. Sunflower (*Helianthus annuus*).* Sparse.

MARSH PLANTS.

19. Marsh fern (*Dryopteris thelypteris*). Common.
20. Bur reed (*Sparganium eurycarpum*). Sparse.
21. Wapato (*Sagittaria latifolia*). Abundant.
22. Reed (*Phragmites communis*). Abundant.
23. Rice cut-grass (*Homalocenchrus oryzoides*).* Common.
24. Big bulrush (*Scirpus occidentalis*). Abundant.
25. Spike rush (*Eleocharis acicularis*). Common.
26. Spike rush (*Eleocharis acuminata*).
27. Sedge (*Carex utriculata*). Common.
28. Tall dock (*Rumex altissimus*). Sparse.
29. Watercress (*Sisymbrium nasturtium-aquaticum*).* Sparse.
30. Touch-me-not (*Impatiens biflora*).* Sparse.
31. Water hemlock (*Cicuta maculata*). Sparse.

SEMISUBMERGED PLANTS.

Dominants:

32. Wild rice (*Zizania palustris*).* A field of wild rice on north side about 1¾ miles long and from a few to several rods wide. Some reed (*Phragmites*) mixed with it.
33. Big bulrush (*Scirpus occidentalis*).*

Secondary species:

34. Wapato (*Sagittaria latifolia*). Common.
35. Reed (*Phragmites communis*). Common.
36. Spike rush (*Eleocharis acuminata*). Common.
37. Bristly sedge (*Carex comosa*).* Sparse; mature fruit.
38. Water hemlock (*Cicuta maculata*).

SUBMERGED PLANTS.

Dominant:

39. Coontail (*Ceratophyllum demersum*).

Secondary species:

40. Water moss (*Drepanocladus* sp.). Common.
41. Small pondweed (*Potamogeton pusillus*). Common.
42. Eelgrass pondweed (*Potamogeton compressus*). Common.
43. Sago pondweed (*Potamogeton pectinatus*). Abundant.
44. Curly pondweed (*Potamogeton perfoliatus richardsonii*).* Common.
45. Illinois pondweed (*Potamogeton illinoensis*).* Common.
46. Bushy pondweed (*Najas flexilis*). Common.
47. Water smartweed (*Polygonum amphibium*). Common.
48. White water crowfoot (*Batrachium divaricatum*). Common.
49. Water milfoil (*Myriophyllum spicatum*).
50. Spatterdock (*Nymphaea advena*). Common.
51. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

Dominant:
52. Star duckweed (*Lemna trisulca*).

Secondary species:
53. Small duckweed (*Lemna minor*).
54. Big duckweed (*Spirodela polyrhiza*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 21, 24 (33), 32, 34, 39, 41, 43, 46, 52, 53, and 54; those of less importance are: Nos. 1, 2, 5, 6 (25), 7, 11, 20, 23, 26 (36), 27, 29, 37, 42, 44, 45, 47, 49, and 50; the remainder are of no known value.

WATTS LAKE, CHERRY COUNTY.

August 29, 1915.

Description.—Large marsh at west end of lake, which it is not safe to penetrate on account of the soft mucky bottom. Lake proper is mostly open water; depth 5 to 6 feet; bottom largely muck. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as for Dewey and Hackberry Lakes. In addition the following:

1. Sensitive fern (*Onoclea sensibilis*).* Common on mucky shore; in fruit.
2. Water smartweed (*Polygonum amphibium*).* Not abundant; flowers.
3. Whorled loosestrife (*Lysimachia quadrifolia*).* Sparse.

MARSH PLANTS.

Dominants:
4. Reed (*Phragmites communis*).
5. Big bulrush (*Scirpus occidentalis*).

Secondary species:
6. Bur reed (*Sparganium eurycarpum.*)
7. Cat-tail (*Typha latifolia*).
8. Wapato (*Sagittaria latifolia*).* Common.
9. Wild rice (*Zizania palustris*). Abundant. A rice field in middle of marsh comprises about one-fifth of entire area.
10. Spike rush (*Eleocharis acuminata*).
11. Sedge (*Carex utriculata*).
12. Rush (*Juncus dudleyi*). Sparse.
13. Willows along marsh bank (*Salix*).

SEMISUBMERGED PLANTS.

Dominants:
14. Big bulrush (*Scirpus occidentalis*).
15. Spike rush (*Eleocharis acuminata*).
16. Wapato (*Sagittaria latifolia*). Common.
17. Wild rice (*Zizania palustris*). Sparse; shows effect of high water.
18. Reed (*Phragmites communis*). Common.
19. Water smartweed (*Polygonum amphibium*).
20. Water hemlock (*Cicuta maculata*). Sparse.

Other smaller sedges and rushes listed among marsh plants occur also in shallow water.

SUBMERGED PLANTS.

Dominant:
21. Eelgrass pondweed (*Potamogeton compressus*).

Secondary species:
22. Water moss (*Drepanocladus* sp.) Common.
23. Sago pondweed (*Potamogeton pectinatus*). Abundant.
24. Small pondweed (*Potamogeton pusillus*). Common.
25. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
26. Illinois pondweed (*Potamogeton illinoensis*). Common.
27. Long-leaved pondweed (*Potamogeton americanus*). Common.
28. Bushy pondweed (*Najas flexilis*). Common.
29. Water smartweed (*Polygonum amphibium*).
30. Coontail (*Ceratophyllum demersum*). Common.
31. Spatterdock (*Nymphaea advena*). Common.
32. Water milfoil (*Myriophyllum spicatum*). Abundant.
33. An alga (*Nostoc verrucosum*). Abundant.

FLOATING PLANTS.

34. Big duckweed (*Spirodela polyrhiza*).
35. Small duckweed (*Lemna minor*).
36. Star duckweed (*Lemna trisulca*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 5 (14), 8 (16), 9 (17), 23, 24, 28, 30, 34, 35, and 36; those of less importance are: Nos. 2 (19, 29), 6, 10 (15), 11, 21, 25, 26, 27, 31, and 32; the remainder are of no known value.

TROUT LAKE, CHERRY COUNTY.

August 31, 1915.

Description.—Considerable marsh on southeast side of lake; small amount on south and west sides. Open water extensive; greatest average depth 8 to 9 feet. Outlet into Ballard swamp.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as listed for neighboring bodies of water. In addition the following:

1. Sedge (*Carex scoparia*).* On wet shore and in bog.

MARSH PLANTS.

Dominants:

2. Reed (*Phragmites communis*).
3. Big bulrush (*Scirpus occidentalis*).

Secondary species:

4. Wapato (*Sagittaria latifolia*). Common.
5. Wild rice (*Zizania palustris*). Abundant.
6. Spike rush (*Eleocharis acuminata*). Common.
7. Water hemlock (*Cicuta maculata*). Sparse.
8. Burweed (*Iva xanthifolia*). Common.

Other smaller sedges and rushes listed for neighboring bodies of water are common in the marsh and bog areas. The marsh consists of rice patches alternating with rush fields.

SEMISUBMERGED PLANTS.

Dominant:

9. Big bulrush (*Scirpus occidentalis*).

Secondary species:

10. Cat-tail (*Typha latifolia*). Sparse.
11. Wapato (*Sagittaria latifolia*). Common.
12. Reed (*Phragmites communis*). Abundant.
13. Dropseed (*Sporobolus asperifolius*). In shallow water.
14. River bulrush (*Scirpus fluviatilis*).* Sparse.
15. Spike rush (*Eleocharis acuminata*).
16. Water smartweed (*Polygonum amphibium*). Common.
17. Water hemlock (*Cicuta maculata*). In shallow water.

SUBMERGED PLANTS.

Dominants:

18. Coontail (*Ceratophyllum demersum*). Abundant.
19. Water milfoil (*Myriophyllum spicatum*). Abundant.

Secondary species:

20. Small pondweed (*Potamogeton pusillus*).*

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 3 (9), 4 (11), 5, 14, 18, and 20; those of less importance are: Nos. 1, 6 (15), 16, and 19; the remainder are of no known value.

PELICAN LAKE, CHERRY COUNTY.

September 1, 1915.

Description.—Very little marsh; small swamp region at west end. Depth 7 to 8 feet (average greatest); bottom mostly mucky. No outlet or inlet.

Distribution of Vegetation.

The neck of water connecting Rat and Beaver Lakes has a sparse stand of wild rice (*Zizania palustris*), and the following are abundant: Wapato (*Sagittaria latifolia*) and water smartweed (*Polygonum amphibium*). The submerged vegetation is about the same as for Rat Lake.

SHORE PLANTS.

A mixture of grasses, etc., as listed for neighboring lakes.[1]

MARSH PLANTS.

1. Marsh fern (*Dryopteris thelypteris*). Common.
2. Cat-tail (*Typha latifolia*). Common.
3. Bur reed (*Sparganium eurycarpum*). Common.
4. Wapato (*Sagittaria latifolia*). Abundant.
5. Reed (*Phragmites communis*). Abundant.
6. Big bulrush (*Scirpus occidentalis*). Abundant.
7. Spike rush (*Eleocharis acicularis*). Common.
8. Richweed (*Pilea pumila*).
9. Marsh mint (*Stachys palustris*).
10. Mint (*Mentha canadensis*).
11. Sticktight (*Bidens trichosperma*). Common.

SEMISUBMERGED PLANTS.

Dominant:

12. Big bulrush (*Scirpus occidentalis*).

Secondary species:

13. Cat-tail (*Typha latifolia*). Common.
14. Wapato (*Sagittaria latifolia*). Common.
15. Wild rice (*Zizania palustris*). Common.
16. Reed (*Phragmites communis*). Common.
17. Spike rush (*Eleocharis acuminata*). A few acres of rice along northeast shore in shallow water.

SUBMERGED PLANTS.

Dominants:

18. Variable pondweed (*Potamogeton heterophyllus*).* Immature fruit.
19. Coontail (*Ceratophyllum demersum*).

Secondary species:

20. Sago pondweed (*Potamogeton pectinatus*).
21. Floating pondweed (*Potamogeton natans*).
22. Small pondweed (*Potamogeton pusillus*). Abundant.
23. Bushy pondweed (*Najas flexilis*). Abundant.
24. Water smartweed (*Polygonum amphibium*).

FLOATING PLANTS.

25. Big duckweed (*Spirodela polyrhiza*). Common.
26. Small duckweed (*Lemna minor*). Common.
27. Star duckweed (*Lemna trisulca*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 4 (14), 6 (12), 15, 18, 19, 20, 22, 23, 25, 26, and 27; those of less importance are: Nos. 3, 7, 11, 17, 21, and 24; the remainder are of no known value.

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[1] The following two species have been recorded from Pelican Lake: Wood chess (*Bromus ciliatus*), Smith, J. G., Rept. Nebraska State Bd. Agr., 1892, p. 286, (1893); and a sedge (*Carex douglasii*), Smith, J. G., and Pound, Roscoe, Botanical Survey of Nebraska II, p. 26, 1893. The last-named plant may have some slight value as duck food.

RAT LAKE, CHERRY COUNTY.

September 3–4, 1915.

Description.—Little or no marsh. Fresh water, mostly open; greatest average depth, 8 feet; bottom mostly sandy. Inlet from Beaver Lake, these two lakes being connected by a strip of water a few rods wide.

Distribution of Vegetation.

SHORE PLANTS.

1. Wild millet (*Echinochloa crus-galli*).* Mature fruit; common.
2. Satin grass (*Muhlenbergia foliosa*).* Flowers.
3. Wild rye (*Elymus canadensis*). Common.
4. Indian grass (*Sorghastrum nutans*).* Flowers.
5. Richweed (*Pilea pumila*).
6. Water smartweed (*Polygonum amphibium*). Common.
7. Bush clover (*Lespedeza capitata*).* Sparse.
8. Prairie trefoil (*Hosackia americana*).* Mature fruit; abundant on higher sandy shore of lake margin.
9. Evening primrose (*Oenothera oakesiana*).* Sparse.
10. Mint (*Mentha canadensis*).
11. Blue verbena (*Verbena hastata*).* Flowers.
12. Prairie sage (*Artemisia gnaphalodes*).* Flowers; rare.
13. Goldenrod (*Solidago altissima*).* Flowers.
14. Bushy goldenrod (*Euthamia graminifolia*).* Flowers.
15. White wreath-aster (*Aster multiflorus*).* Flowers; common.

Other grasses, small sedges, etc., as listed for neighboring bodies of water.

MARSH PLANTS.

Little or no marsh.

SEMISUBMERGED PLANTS.

Dominants:

16. Wapato (*Sagittaria latifolia*).
17. Spike rush (*Eleocharis acuminata*).

Secondary species:

18. Big bulrush (*Scirpus occidentalis*).
19. Water smartweed (*Polygonum amphibium*).* Mature fruit.

SUBMERGED PLANTS.

Dominant:

20. Coontail (*Ceratophyllum demersum*).

Secondary species:

21. Musk grass (*Chara* spp).* Common.
22. Floating pondweed (*Potamogeton natans*).
23. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
24. Small pondweed (*Potamogeton pusillus*). Abundant.
25. Sago pondweed (*Potamogeton pectinatus*). Common.
26. Illinois pondweed (*Potamogeton illinoensis*). Common.
27. Bushy pondweed (*Najas flexilis*). Common.
28. Spike rush (*Eleocharis acicularis*). Abundant.
29. Water smartweed (*Polygonum amphibium*). Rare.
33. Star duckweed (*Lemna trisulca*). Abundant.

FLOATING PLANTS.

31. Big duckweed (*Spirodela polyrhiza*).
32. Small duckweed (*Lemna minor*).
33. Star duckweed (*Lemna trisulca*). Abundant.

Wild-duck food.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 16, 18, 20, 21, 24, 25, 27, 31, 32, and 33; those of less importance are: Nos. 1, 6, 17, 19 (29), 22, 23, 26, 28, and 30; the remainder are of no known value.

BEAVER LAKE, CHERRY COUNTY.

September 3–4, 1915.

Description.—No marsh, grazed to shore line. Average greatest depth, 14 to 15 feet; bottom sandy.

Distribution of Vegetation.

SHORE PLANTS.

Upland vegetation to shore line; closely grazed. No marsh.

SEMISUBMERGED PLANTS.

1. Wapato (*Sagittaria latifolia*). Scarce.
2. Big bulrush (*Scirpus occidentalis*). Scarce.

SUBMERGED PLANTS.

Dominant:

3. Coontail (*Ceratophyllum demersum*).

Secondary species:

4. Sago pondweed (*Potamogeton pectinatus*).
5. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
6. Illinois pondweed (*Potamogeton illinoensis*).
7. Small pondweed (*Potamogeton pusillus*). Abundant.
8. Floating pondweed (*Potamogeton natans*).
9. Spike rush (*Eleocharis acicularis*).
10. Water smartweed (*Polygonum amphibium*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 2, 3, 4, and 7; those of less importance are: Nos. 5, 6, 8, 9, and 10; the remainder are of no known value.

WENDLER SWAMP, CHERRY COUNTY.

September 4 and 10, 1915.

Description.—Good stand of wild rice over entire swamp. Fresh water, fed by springs; very little open; bottom very mucky; average greatest depth, 3 to 4 feet; no inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

1. Arrow-grass (*Triglochin maritima*). Common.
2. Wapato (*Sagittaria latifolia*).
3. Wild millet (*Echinochloa crus-galli*). Common.
4. Switchgrass (*Panicum virgatum*).
5. Rice cut-grass (*Homalocenchrus oryzoides*).
6. Satin grass (*Muhlenbergia foliosa*).
7. Sedge (*Carex scoparia*).* Abundant.
8. Rush (*Juncus torreyi*).*
9. Rush (*Juncus marginatus*).*
10. Water smartweed (*Polygonum amphibium*).

Other grasses, sedges, etc., as listed for neighboring bodies of water.

SEMISUBMERGED PLANTS.

Dominants:

11. Wild rice (*Zizania palustris*).
12. Reed (*Phragmites communis*).
13. Big bulrush (*Scirpus occidentalis*).

Secondary species:

14. Cat-tail (*Typha latifolia*).
15. Bur reed (*Sparganium eurycarpum*).
16. Wapato (*Sagittaria latifolia*).
17. Spike rush (*Eleocharis acuminata*).
18. Tall dock (*Rumex altissimus*).
19. Water hemlock (*Cicuta maculata*).*
20. Buckbean (*Menyanthes trifoliata*).*

SUBMERGED PLANTS.

Dominants:

21. Coontail (*Ceratophyllum demersum*).
22. Spatterdock (*Nymphaea advena*).* Seedlings.

Secondary species:

23. Musk grass (*Chara* sp.).* Abundant.
24. Water moss (*Drepanocladus* sp.). Abundant.
25. Sago pondweed (*Potamogeton pectinatus*). Abundant.
26. Eelgrass pondweed (*Potamogeton compressus*). Common.
27. Small pondweed (*Potamogeton pusillus*). Common.
28. Illinois pondweed (*Potamogeton illinoensis*).
29. Floating pondweed (*Potamogeton natans*).
30. Variable pondweed (*Potamogeton heterophyllus*).
31. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
32. Bushy pondweed (*Najas flexilis*). Common.
33. Water smartweed (*Polygonum amphibium*). Abundant.
34. White water crowfoot (*Batrachium divaricatum*).
35. Spatterdock (*Nymphaea advena*). Common.
36. Water milfoil (*Myriophyllum spicatum*). Abundant.
37. Bladderwort (*Utricularia vulgaris*). Abundant.

FLOATING PLANTS.

38. Big duckweed (*Spirodela polyrhiza*).
39. Small duckweed (*Lemna minor*).
40. Star duckweed (*Lemna trisulca*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2 (16), 3, 11, 13, 21, 23, 25, 27, 30, 32, 38, 39, and 40; those of less importance are: Nos. 1, 4, 5, 7, 10 (33), 15, 17, 20, 22 (35), 26, 28, 29, 31, 34, and 36; the remainder are of no known value.

SWEETWATER LAKES, CHERRY COUNTY.

September 6, 1915.

Description.—Marshy at west end. Well filled with submerged vegetation. Average greatest depth about 3 to 3½ feet; bottom mostly sandy. Overflow from one lake to another during high water.

Distribution of Vegetation.

SHORE PLANTS.

Typical mixture of grasses, etc., as listed for other lakes. Grazed mostly to shore line.

MARSH PLANTS.

1. Water plantain (*Alisma subcordatum*). Common.
2. Wapato (*Sagittaria latifolia*).
3. Reed (*Phragmites communis*).
4. Big bulrush (*Scirpus occidentalis*).
5. Spike rush (*Eleocharis acuminata*).
6. Rush (*Juncus torreyi*).*
7. St. John's-wort (*Hypericum punctatum*).* Mature fruit.
8. Willow herb (*Epilobium lineare*).*
9. Water hemlock (*Cicuta maculata*).
10. Water hemlock (*Cicuta bulbifera*).*
11. Skullcap (*Scutellaria galericulata*).* Flowers.
12. Purple boneset (*Eupatorium purpureum*).* Flowers.
13. Sticktight (*Bidens trichosperma*).* Flowers.
14. Willow aster (*Aster salicifolius*).* Flowers.
15. Sunflower (*Helianthus annuus*).* Flowers.

SEMISUBMERGED PLANTS.

Dominants:

16. Wapato (*Sagittaria latifolia*).
17. Spike rush (*Eleocharis acuminata*).

Secondary species:

18. Water plantain (*Alisma subcordatum*).*
19. Cord-grass (*Spartina michauxiana*).
20. Big bulrush (*Scirpus occidentalis*).
21. Water smartweed (*Polygonum amphibium*).

SUBMERGED PLANTS.

Dominants:

22. Musk grass (*Chara* sp.).
23. Small pondweed (*Potamogeton pusillus*).
24. Waterweed (*Philotria canadensis*).* Flowers; only place found in this group of lakes in eastern Cherry County.

Secondary species:

25. Water moss (*Drepanocladus* sp.). Abundant.
26. Sago pondweed (*Potamogeton pectinatus*). Abundant.
27. Variable pondweed (*Potamogeton heterophyllus*).
28. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
29. Bushy pondweed (*Najas flexilis*).
30. Water smartweed (*Polygonum amphibium*).
31. White water crowfoot (*Batrachium divaricatum*).* Common.
32. Coontail (*Ceratophyllum demersum*).
33. Spatterdock (*Nymphaea advena*). Algae abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2 (16), 4 (20), 22, 23, 26, 27, 29, and 32; those of less importance are: Nos. 1 (18), 5 (17), 13, 19, 21 (30), 24, 28, 31, and 33; the remainder are of no known value.

TWENTY-ONE LAKE, CHERRY COUNTY.

September 6, 1915.

Description.—Marshy at west end. Water perhaps a little alkaline; average greatest depth, 7½ to 8 feet; bottom, sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as for other lakes, and in addition the following:

1. Long-leaved reedgrass (*Calamovilfa longifolia*).*
2. Big bulrush (*Scirpus occidentalis*). Abundant on wet shore.
3. Sedge (*Carex diandra*).* Mature fruit.
4. Mint (*Mentha canadensis*).*
5. Goldenrod (*Solidago altissima*).*
6. Groundsel (*Senecio riddellii*).* Flowers.

SEMISUBMERGED PLANTS.

Dominant:

7. Big bulrush (*Scirpus occidentalis*).

Secondary species:

8. Wapato (*Sagittaria latifolia*). Abundant.
9. Reed (*Phragmites communis*). Abundant.
10. Cord-grass (*Spartina michauxiana*).
11. Spike rush (*Eleocharis acuminata*). Abundant.
12. Water smartweed (*Polygonum amphibium*).

SUBMERGED PLANTS.

Dominants:

13. Sago pondweed (*Potamogeton pectinatus*).
14. Curly pondweed (*Potamogeton perfoliatus richardsonii*).

Secondary species:

15. Floating pondweed (*Potamogeton natans*).
16. Illinois pondweed (*Potamogeton illinoensis*).
17. Eelgrass pondweed (*Potamogeton compressus*).
18. Small pondweed (*Potamogeton pusillus*). Abundant.
19. Bushy pondweed (*Najas flexilis*).
20. Coontail (*Ceratophyllum demersum*). Common.
21. Bladderwort (*Utricularia vulgaris*). Common.

—. Algae abundant.

FLOATING PLANTS.

22. Big duckweed (*Spirodela polyrhiza*).
23. Small duckweed (*Lemna minor*).
24. Star duckweed (*Lemna trisulca*). Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2 (7), 8, 13, 18, 19, 20, 22, 23, and 24; those of less importance are: Nos. 3, 10, 11, 12, 14, 15, 16, and 17; the remainder are of no known value.

MARSH LAKES, CHERRY COUNTY.

September 7, 1915.

Description.—These lakes in reality form one large lake, the parts of which are distinguished only in name. Fresh water, well filled with vegetation, small proportion open; average greatest depth as follows: South Marsh Lake, 7 to 8 feet; Middle Marsh Lake, 10 to 12 feet; and North Marsh Lake, 6 to 7 feet. Bottom in general mucky, in a few places sandy. No inlet or outlet.

Distribution of Vegetation.

Very little open water on South Marsh Lake. Large body of open water, surrounded by dense growth of vegetation in Middle Marsh Lake.

SHORE PLANTS.

In addition to grasses, sedges, etc., listed for other lakes, there are:

1. Three-way sedge (*Dulichium arundinaceum*).*
2. Water pepper (*Polygonum punctatum*).* Mature fruit.
3. Three-finger (*Potentilla monspeliensis*).*
4. Water hemlock (*Cicuta bulbifera*).*
5. Thorowort (*Eupatorium perfoliatum*).* Flowers.
6. Purple boneset (*Eupatorium purpureum*).*
7. Sunflower (*Helianthus annuus*).* Flowers.
8. Sticky aster (*Machaeranthera sessiliflora*).* Flowers.
9. Bur marigold (*Bidens laevis*).* Flowers.
10. New England aster (*Aster novae-angliae*).* Flowers to immature fruit.
11. Rush lettuce (*Lygodesmia juncea*).* Flowers.

SEMISUBMERGED PLANTS.

Dominants:

12. Reed (*Phragmites communis*).
13. Big bulrush (*Scirpus occidentalis*).

Secondary species:

14. Cat-tail (*Typha latifolia*). Common.
15. Bur reed (*Sparganium eurycarpum*). Sparse.
16. Wapato (*Sagittaria latifolia*). Abundant.
17. Wild rice (*Zizania palustris*). Abundant.
18. Spike rush (*Eleocharis acuminata*). Abundant.
19. Bristly sedge (*Carex comosa*). Abundant.
20. Rush (*Juncus marginatus*). A field and other scattered patches.
21. Water smartweed (*Polygonum amphibium*).

SUBMERGED PLANTS.

Dominants:

22. Water moss (*Drepanocladus* sp.).
23. Sago pondweed (*Potamogeton pectinatus*).
24. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
25. Water milfoil (*Myriophyllum spicatum*).* Immature fruit.

Secondary species:

26. Musk grass (*Chara* sp.) Common.
27. Bur reed (*Sparganium eurycarpum*). Abundant.
28. Floating pondweed (*Potamogeton natans*). Common.
29. Illinois pondweed (*Potamogeton illinoensis*).
30. Small pondweed (*Potamogeton pusillus*). Abundant.
31. Eelgrass pondweed (*Potamogeton compressus*). Common.
32. Variable pondweed (*Potamogeton heterophyllus*).
33. Bushy pondweed (*Najas flexilis*). Common.
34. Spike rush (*Eleocharis acicularis*). Abundant.
35. Water smartweed (*Polygonum amphibium*). Common.
36. White water crowfoot (*Batrachium divaricatum*).
37. Coontail (*Ceratophyllum demersum*). Abundant.
38. Spatterdock (*Nymphaea advena*). Common.
39. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

40. Big duckweed (*Spirodela polyrhiza*).
41. Small duckweed (*Lemna minor*).
42. Star duckweed (*Lemna trisulca*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 13, 16, 17, 23, 26, 30, 32, 33, 37, 40, 41, and 42; those of less importance are: Nos. 2, 9, 15 (27), 18, 19, 21 (35), 24, 25, 28, 29, 31, 34, 36, and 38; the remainder are of no known value.

RED DEER LAKE, CHERRY COUNTY.

September 10, 1915.

Description.—Little or no marsh. Mostly open water; average greatest depth, 7 to 8 feet. Bottom generally sandy. Inlet from Ballard Swamp during overflow period; outlet into Goose Creek and thence into Niobrara River.

Distribution of Vegetation.

SHORE PLANTS.

Typical mixture of grasses, sedges, goldenrods, etc., as listed for other lakes, including the following:

1. Saltgrass (*Distichlis spicata*).

SEMISUBMERGED PLANTS.

Dominants:
2. Cat-tail (*Typha latifolia*).
3. Big bulrush (*Scirpus occidentalis*).

Secondary species:
4. Wapato (*Sagittaria latifolia*). Common.
5. Reed (*Phragmites communis*). Common.

SUBMERGED PLANTS.

Dominants:
6. Sago pondweed (*Potamogeton pectinatus*).
7. Coontail (*Ceratophyllum demersum*).

Secondary species:
8. Musk grass (*Chara* sp.). Abundant.
9. Floating pondweed (*Potamogeton natans*).
10. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
11. Illinois pondweed (*Potamogeton illinoensis*).
12. Small pondweed (*Potamogeton pusillus*).
13. White water crowfoot (*Batrachium divaricatum*).

FLOATING PLANTS.

14. Greater duckweed (*Spirodela polyrhiza*). Abundant.
15. Small duckweed (*Lemna minor*). Abundant.
16. Star duckweed (*Lemna trisulca*). Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 3, 4, 6, 7, 8, 12, 14, 15, and 16; those of less importance are: Nos. 1, 9, 10, 11, and 13; the remainder are of no known value.

BALLARD SWAMP, CHERRY COUNTY.

September 10, 1915.

Description.—Vegetation abundant and in good condition. Fresh water; very little open; depth, 4 to 5 feet. Bottom in general very mucky; sandy in a few places. Inlet from Trout Lake; outlet during high water into Red Deer Lake.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, etc., as listed for neighboring waters, including the following:

1. Common plantain (*Plantago major*).* Mature fruit.
2. Plantain (*Plantago purshii*).* Flowers.
3. Satin grass (*Muhlenbergia squarrosa*).* Flowers.
4. Tussock sedge (*Carex stricta*).* Mature fruit.
5. Closed gentian (*Gentiana andrewsii*).* Flowers.
6. Buckbean (*Menyanthes trifoliata*).*
7. Purple foxglove (*Gerardia besseyana*).*
8. Small cleavers (*Galium trifidum*).* Immature fruit.
9. Goldenrod (*Solidago rigida*).* Flowers, to mature fruit.
10. Goldenrod (*Solidago serotina*).* Flowers.
11. Bushy goldenrod (*Euthamia graminifolia*).* Flowers.
12. Sticktight (*Bidens trichosperma*).* Flowers, to mature fruit.
13. Willow aster (*Aster salicifolius*).* Flowers.

SEMISUBMERGED PLANTS.

Dominants:

14. Wild rice (*Zizania palustris*). Good stand of rice over most of swamp area.
15. Reed (*Phragmites communis*).
16. Big bulrush (*Scirpus occidentalis*).

Secondary species:

17. Wapato (*Sagittaria latifolia*).
18. River bulrush (*Scirpus fluviatilis*).
19. Spike rush (*Eleocharis acuminata*).
20. Sedge (*Carex scoparia*).
21. Golden dock (*Rumex persicarioides*).* Mature fruit; sparse.
22. Water hemlock (*Cicuta maculata*).

SUBMERGED PLANTS.

Dominants:

23. Small pondweed (*Potamogeton pusillus*).
24. Coontail (*Ceratophyllum demersum*).
25. Spatterdock (*Nymphaea advena*).* Seedlings.

Secondary species:

26. Musk grass (*Chara* sp.). Abundant.
27. Floating pondweed (*Potamogeton natans*).
28. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
29. Illinois pondweed (*Potamogeton illinoensis*).
30. Eelgrass pondweed (*Potamogeton compressus*). Abundant.
31. Sago pondweed (*Potamogeton pectinatus*). Abundant.
32. Small pondweed (*Potamogeton pusillus*).
33. Bushy pondweed (*Najas flexilis*). Common.
34. Water smartweed (*Polygonum amphibium*).
35. White water crowfoot (*Batrachium divaricatum*).
36. Water milfoil (*Myriophyllum spicatum*).

FLOATING PLANTS.

37. Big duckweed (*Spirodela polyrhiza*). Abundant.
38. Small duckweed (*Lemna minor*). Abundant.
39. Star duckweed (*Lemna trisulca*). Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 14, 16, 17, 18, 23, 24, 26, 31, 32, 33, 37, 38, and 39; those of less importance are: Nos. 4, 6, 8, 12, 19, 20, 25, 27, 28, 29, 30, 34, 35, and 36; the remainder are of no known value.

BIG ALKALI LAKE, CHERRY COUNTY.

September 13, 1915.

Description.—Little or no marsh. Water, alkaline; average greatest depth, 10 to 12 feet; bottom, sandy. No outlet or inlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, goldenrods, etc., as listed for neighboring lakes:

1. Saltgrass (*Distichlis spicata*). Common.

SEMISUBMERGED PLANTS.

Dominants:
2. Big bulrush (*Scirpus occidentalis*).
3. Spike rush (*Eleocharis acuminata*).

SUBMERGED PLANTS.

4. Small pondweed (*Potamogeton pusillus*). Abundant.
5. Sago pondweed (*Potamogeton pectinatus*). Sparse.
6. Water milfoil (*Myriophyllum spicatum*). Sparse.

–. Very little submerged vegetation.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2, 4, and 5; those of less importance are: Nos. 1, 3, and 6.

MOLLY MARSH, CHERRY COUNTY.

September 13,1915.

Description.—Comparatively little open water; depth, 3 to 4 feet; bottom mucky. No outlet or inlet.

Distribution of Vegetation.

SHORE PLANTS.

A mixture of grasses, sedges, etc., as found on near-by lakes; nothing new.

SEMISUBMERGED PLANTS.

Dominant:
1. Great bulrush (*Scirpus occidentalis*).

Secondary species:
2. Bur reed (*Sparganium eurycarpum*).
3. Wapato (*Sagittaria latifolia*).
4. Reed (*Phragmites communis*).
5. River bulrush (*Scirpus fluviatilis*). Common.
6. Spike rush (*Eleocharis acuminata*).
7. Water smartweed (*Polygonum amphibium*). Common.
8. Water hemlock (*Cicuta maculata*). Sparse.

SUBMERGED PLANTS.

9. Sago pondweed (*Potamogeton pectinatus*).
10. Coontail (*Ceratophyllum demersum*).

Secondary species:
11. Floating pondweed (*Potamogeton natans*).
12. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
13. Illinois pondweed (*Potamogeton illinoensis*).
14. Eelgrass pondweed (*Potamogeton compressus*).
15. Small pondweed (*Potamogeton pusillus*). Common.
16. Bushy pondweed (*Najas flexilis*). Common.
17. Water smartweed (*Polygonum amphibium*).
18. White water crowfoot (*Batrachium divaricatum*). Abundant.
19. Spatterdock (*Nymphaea advena*).
20. Water milfoil (*Myriophyllum spicatum*).
21. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

22. Big duckweed (*Spirodela polyrhiza*). Abundant.
23. Small duckweed (*Lemna minor*). Abundant.
24. Star duckweed (*Lemna trisulca*). Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 3, 5, 9, 10, 15, 16, 22, 23, and 24; those of less importance are: Nos. 2, 6, 7 (17), 11, 12, 13, 14, 18, 19, and 20; the remainder are of no known value.

HAY LAKE, CHERRY COUNTY.

September 14, 1915.

Description.—No marsh. Lake well filled with submerged vegetation; bottom mostly mucky; depth, 6 feet. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

In addition to others listed for near-by waters, there are:

1. Switchgrass (*Panicum virgatum*).* Mature fruit.
2. White wreath-aster (*Aster multiflorus*).* Flowers.

SEMISUBMERGED PLANTS.

Dominant:
3. Big bulrush (*Scirpus occidentalis*).

Secondary species:
4. Cat-tail (*Typha latifolia*).
5. Spike rush (*Eleocharis acuminata*).

SUBMERGED PLANTS.

Dominant:
6. Sago pondweed (*Potamogeton pectinatus*).*

Secondary species:
7. Curly pondweed (*Potamogeton perfoliatus richardsonii*).
8. Illinois pondweed (*Potamogeton illinoensis*).
9. Eelgrass pondweed (*Potamogeton compressus*).
10. Bushy pondweed (*Najas flexilis*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 3, 6, and 10; those of less importance are: Nos. 1, 5, 7, 8, and 9; the remainder are of no known value.

SOUTH CODY LAKE, CHERRY COUNTY.

September 18–19, 1915.

Description.—Marshy at east and west ends; considerable open water: average greatest depth, 4 to 5 feet; bottom generally mucky. Inlet from the west; overflow into North Cody Lake during high water.

Distribution of Vegetation.

SHORE PLANTS.

Typical wet-meadow plants.

1. Arrow-grass (*Triglochin maritima*).* Mature fruit.
2. Wild millet (*Echinochloa crus-galli*).*
3. Switchgrass (*Panicum virgatum*).*
4. Cord-grass (*Spartina michauxiana*).*
5. Squirrel-tail (*Hordeum jubatum*).*
6. Satin grass (*Muhlenbergia foliosa*).*
7. Sedge (*Cyperus speciosus*).* Mature fruit.
8. Rush (*Juncus torreyi*).*
9. Rush (*Juncus balticus*).*
10. Richweed (*Pilea pumila*).* Immature fruit.
11. Water smartweed (*Polygonum amphibium*).* Flowers to mature fruit.
12. Water pepper (*Polygonum punctatum*).*
13. Heart's-ease (*Polygonum pennsylvanicum*).* Mature fruit.
14. Lamb's-quarters (*Chenopodium album*).*
15. Water hemlock (*Cicuta bulbifera*).*
16. Marsh mint (*Stachys palustris*).* Flowers.
17. Mint (*Mentha canadensis*).* Flowers.
18. Water hoarhound (*Lycopus asper*).* Mature fruit.
19. Hairy germander (*Teucrium occidentale*).* Mature fruit.
20. Small cleavers (*Galium trifidum*).* Immature fruit.
21. Ragweed (*Ambrosia elatior*).* Flowers, to mature fruit.
22. Goldenrod (*Solidago altissima*).* Flowers.
23. Sunflower (*Helianthus annuus*).* Flowers.
24. Bur marigold (*Bidens laevis*).* Flowers.
25. Willow aster (*Aster salicifolius*).* Flowers.

SEMISUBMERGED PLANTS.

Dominants:

26. Tule (*Scirpus validus*).* Mature fruit.
27. Reed (*Phragmites communis*).*

Secondary species:

28. Cat-tail (*Typha latifolia*).*
29. Bur reed (*Sparganium eurycarpum*).* Mature fruit; common.
30. Water plantain (*Alisma subcordatum*).* Common.
31. Wapato (*Sagittaria latifolia*).* Mature fruit.
32. Wild rice (*Zizania palustris*).*
33. Cord-grass (*Spartina michauxiana*). Abundant.
34. Three-square (*Scirpus americanus*).* Common.
35. River bulrush (*Scirpus fluviatilis*).* Mature fruit; common.
36. Spike rush (*Eleocharis*, probably *acicularis*).*
37. Bristly sedge (*Carex comosa*).* Mature fruit; abundant.
38. Curly dock (*Rumex crispus*).* Mature fruit; common.
39. Water smartweed (*Polygonum amphibium*).
40. Water hemlock (*Cicuta maculata*).* Flowers, to immature fruit.
41. Swamp milkweed (*Asclepias incarnata*).* Mature fruit.

SUBMERGED PLANTS.

Dominants:

42. Floating pondweed (*Potamogeton natans*).*
43. Coontail (*Ceratophyllum demersum*).*

Secondary species:

44. Musk grass (*Chara* sp.).* Common.
45. Water moss (*Drepanocladus kneiffi* var. *laxum*).
46. Curly pondweed (*Potamogeton perfoliatus richardsonii*).*
47. Variable pondweed (*Potamogeton heterophyllus*).
48. Sago pondweed (*Potamogeton pectinatus*).* Abundant.
49. Eelgrass pondweed (*Potamogeton compressus*).* Common.
50. Small pondweed (*Potamogeton pusillus*).* Winter buds present; common.
51. Bushy pondweed (*Najas flexilis*).* Common.
52. Spike rush (*Eleocharis*, probably *acicularis*).* Common.
53. Water smartweed (*Polygonum amphibium*).
54. Yellow water-crowfoot (*Ranunculus delphinifolius*).
55. Water milfoil (*Myriophyllum spicatum*).* Abundant.
56. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

57. Big duckweed (*Spirodela polyrhiza*).* Common.
58. Small duckweed (*Lemna minor*).* Common.
59. Star duckweed (*Lemna trisulca*).* Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 26, 31, 32, 35, 43, 44, 48, 50, 51, 57, 58, and 59; those of less importance are: Nos. 1, 2, 3, 4 (33), 7 (39, 53), 12, 13, 24, 29, 30, 34, 36, 37, 42, 46, 49, 54, and 55; the remainder are of no known value.

NORTH CODY LAKE, CHERRY COUNTY.

September 20, 1915.

Description.—Average greatest depth 4 feet; bottom generally mucky. Connected with South Cody Lake during high water.

Distribution of Vegetation.

SHORE PLANTS.

–. Typical wet-meadow plants.
1. Cord-grass (*Spartina michauxiana*).
2. Wild millet (*Echinochloa crus-galli*).
3. Switchgrass (*Panicum virgatum*).
4. Squirrel-tail (*Hordeum jubatum*).
5. Satin grass (*Muhlenbergia foliosa*).
6. Sedge (*Cyperus speciosus*).
7. Rush (*Juncus torreyi*).
8. Rush (*Juncus balticus*).
9. Richweed (*Pilea pumila*).
10. Water smartweed (*Polygonum amphibium*).
11. Water pepper (*Polygonum punctatum*).
12. Lamb's-quarters (*Chenopodium album*).
13. Water hemlock (*Cicuta bulbifera*).
14. Water hoarhound (*Lycopus asper*).
15. Marsh mint (*Stachys palustris*).
16. Hairy germander (*Teucrium occidentale*).
17. Small cleavers (*Galium trifidum*).
18. Ragweed (*Ambrosia elatior*).
19. Goldenrod (*Solidago altissima*).
20. Bur marigold (*Bidens laevis*).
21. Sunflower (*Helianthus annuus*).
22. Willow aster (*Aster salicifolius*).

SEMISUBMERGED PLANTS.

Dominants:
23. Reed (*Phragmites communis*).
24. Tule (*Scirpus validus*).

Secondary species:
25. Cat-tail (*Typha latifolia*).
26. Bur reed (*Sparganium eurycarpum*). Common.
27. Water plantain (*Alisma subcordatum*).* Common.
28. Wapato (*Sagittaria latifolia*).
29. Wild rice (*Zizania palustris*). Abundant.
30. Cord-grass (*Spartina michauxiana*). Abundant.
31. Three-square (*Scirpus americanus*). Common.
32. River bulrush (*Scirpus fluviatilis*). Common.
33. Spike rush (*Eleocharis*, probably *acicularis*).
34. Bristly sedge (*Carex comosa*). Abundant.
35. Curly dock (*Rumex crispus*). Common.
36. Water smartweed (*Polygonum amphibium*).
37. Water hemlock (*Cicuta maculata*).
38. Swamp milkweed (*Asclepias incarnata*).

SUBMERGED PLANTS.

Dominant:
39. Coontail (*Ceratophyllum demersum*).

Secondary species:
40. Musk grass (*Chara* sp.).* Common.
41. Water moss (*Drepanocladus* sp.).
42. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
43. Variable pondweed (*Potamogeton heterophyllus*).*
44. Sago pondweed (*Potamogeton pectinatus*). Abundant.
45. Eelgrass pondweed (*Potamogeton compressus*).
46. Bushy pondweed (*Najas flexilis*). Common.
47. Spike rush (*Eleocharis*, probably *acicularis*).
48. Water smartweed (*Polygonum amphibium*). Common.
49. Yellow water-crowfoot (*Ranunculus delphinifolius*).*
50. Water milfoil (*Myriophyllum spicatum*). Abundant.
51. Bladderwort (*Utricularia vulgaris*).*

FLOATING PLANTS.

52. Big duckweed (*Spirodela polyrhiza*). Common.
53. Small duckweed (*Lemna minor*). Common.
54. Star duckweed (*Lemna trisulca*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 24, 28, 29, 32, 39, 40, 43, 44, 46, 52, 53, and 54; those of less importance are: Nos. 1, 2, 3, 6, 10 (36, 48), 11, 20, 26, 27, 31, 33 (47), 34, 42, 45, 49, and 50; the remainder are of no known value.

RED WILLOW LAKE, CHERRY COUNTY.

October 9, 1915.

Description.—Very small amount of marsh at west end. Well filled with vegetation. Fresh water; average greatest depth 4½ feet; bottom mostly sandy. No outlet or inlet. No current except as caused by wind.

Distribution of Vegetation.

SHORE PLANTS.

–. Typical wet-meadow plants.
1. Saltgrass (*Distichlis spicata*).* Mature fruit; abundant.
2. Western wheat-grass (*Agropyron smithii*).* Mature fruit; common.
3. Switchgrass (*Panicum virgatum*).* Mature fruit; abundant.
4. Fragrant sedge (*Cyperus inflexus*).* Mature fruit; abundant.
5. Straw sedge (*Cyperus strigosus*).* Mature fruit; abundant.
6. Three-way sedge (*Dulichium arundinaceum*).* Common.
7. Spike rush (*Eleocharis acicularis*).* Mature fruit; abundant.
8. Rush (*Juncus marginatus*).* Mature fruit.
9. Rush (*Juncus canadensis*).* Mature fruit; abundant.
10. Rush (*Juncus balticus*).* Immature fruit.
11. Rush (*Juncus*, probably *interior*).* Mature fruit.
12. Willow (*Salix prinoides*).* Sparse.
13. Golden dock (*Rumex persicarioides*).* Mature fruit; common.
14. Bushy knotweed (*Polygonum ramosissimum*).* Mature fruit; sparse.
15. Water hemlock (*Cicuta bulbifera*).* Sparse.
16. Bugleweed (*Lycopus uniflorus*).* Flowers, to mature fruit; common.
17. Ragweed (*Ambrosia elatior*).* Flowers; common.
18. Bushy goldenrod (*Euthamia graminifolia*).* Flowers, to mature fruit; common.
19. Bur marigold (*Bidens laevis*).

SEMISUBMERGED PLANTS.

Dominant:
20. Tule (*Scirpus validus*).

Secondary species:
21. Cat-tail (*Typha latifolia*). Sparse.
22. Bur reed (*Sparganium eurycarpum*). Sparse.
23. Water plantain (*Alisma subcordatum*).* Common.
24. Wapato (*Sagittaria latifolia*). Common.
25. Cord-grass (*Spartina michauxiana*). Common.
26. Three-square (*Scirpus americanus*). Common.
27. Water smartweed (*Polygonum amphibium*).* Mature fruit; common.

SUBMERGED PLANTS.

Dominant:
28. Water milfoil (*Myriophyllum spicatum*).* Mature fruit.

Secondary species:
29. An alga (*Nostoc verrucosum*). Abundant.
30. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Common.
31. Variable pondweed (*Potamogeton heterophyllus*).* Mature fruit; common.
32. Sago pondweed (*Potamogeton pectinatus*).* Mature fruit; sparse.
33. Small pondweed (*Potamogeton pusillus*).* Winter buds present.
34. Spike rush (*Eleocharis*, probably *acicularis*).* Common.
35. Water smartweed (*Polygonum amphibium*).*
36. Coontail (*Ceratophyllum demersum*).*
37. Bladderwort (*Utricularia vulgaris*).*

FLOATING PLANT.

38. Star duckweed (*Lemna trisulca*).* Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 20, 24, 31, 32, 33, 36, and 38; those of less importance are: Nos. 1, 3, 4, 5, 7, 22, 23, 25, 26, 27 (35), 28, 30, and 34; the remainder are of no known value.

WHITE WILLOW LAKE, CHERRY COUNTY.

October 10, 1915.

Description.—No marsh. Grazed to shore on south and west sides. Well filled with vegetation. Fresh water; depth 6 to 7 feet; bottom mostly sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

–. Typical wet-meadow plants.
1. Saltgrass (*Distichlis spicata*). Abundant.
2. Western wheat-grass (*Agropyron smithii*). Common.
3. Switchgrass (*Panicum virgatum*). Abundant.
4. Bog reedgrass (*Calamagrostis inexpansa*).* Mature fruit.
5. Fragrant sedge (*Cyperus inflexus*). Abundant.
6. Straw sedge (*Cyperus strigosus*).* Mature fruit.
7. Shining sedge (*Cyperus rivularis*).* Mature fruit.
8. Spike rush (*Eleocharis palustris*).* Mature fruit.
9. Spike rush (*Eleocharis acicularis*). Abundant.
10. Three-way sedge (*Dulichium arundinaceum*). Common.
11. Sedge (*Carex vulpinoidea*).*
12. Sedge (*Carex scoparia*).* Mature fruit.
13. Rush (*Juncus marginatus*).*
14. Rush (*Juncus canadensis*). Abundant.
15. Willow (*Salix*). Sparse.
16. Golden dock (*Rumex persicarioides*). Common.
17. Bushy knotweed (*Polygonum ramosissimum*). Sparse.
18. Water hemlock (*Cicuta bulbifera*). Sparse.
19. Bugleweed (*Lycopus uniflorus*). Common.
20. Ragweed (*Ambrosia elatior*). Common.
21. Bushy goldenrod (*Euthamia graminifolia*). Common.
22. Bur marigold (*Bidens laevis*).

SEMISUBMERGED PLANTS.

Dominant:
23. Tule (*Scirpus validus*).

Secondary species:
24. Wapato (*Sagittaria latifolia*).
25. Cord-grass (*Spartina michauxiana*).* Mature fruit; common.
26. Bog reedgrass (*Calamagrostis inexpansa*).

SUBMERGED PLANTS.

Dominants:
27. Small pondweed (*Potamogeton pusillus*).* Mature fruit; winter buds.
28. Water milfoil (*Myriophyllum spicatum*).

Secondary species:
29. Musk grass (*Chara* sp.).* Common.
30. Water moss (*Drepanocladus* sp.).
31. Curly pondweed (*Potamogeton perfoliatus richardsonii*).* Abundant.
32. Variable pondweed (*Potamogeton heterophyllus*).
33. Sago pondweed (*Potamogeton pectinatus*).* Common.
34. Bushy pondweed (*Najas flexilis*). Rare.
35. Spike rush (*Eleocharis*, probably *acicularis*). Common.
36. Water smartweed (*Polygonum amphibium*). Common.
37. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

38. Butterflywort (*Riccia natans*).*
39. Big duckweed (*Spirodela polyrhiza*).
40. Star duckweed (*Lemna trisulca*).* Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 23, 24, 27, 29, 32, 33, 34, 39, and 40; those of less importance are: Nos. 1, 3, 5, 6, 7, 8, 9, 11, 12, 25, 28, 31, 35, and 36; the remainder are of no known value.

SPECKELMIRE LAKE, CHERRY COUNTY.

October 12, 1915.

Description.—Marsh at west end. Fresh water; average greatest depth 3 to 4 feet; bottom mostly sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as listed for neighboring lakes; nothing new.

SEMISUBMERGED PLANTS.

Dominants:

1. Cat-tail (*Typha latifolia*).
2. Tule (*Scirpus validus*).

Secondary species:

3. Bur reed (*Sparganium eurycarpum*).
4. Arrow-grass (*Triglochin maritima*).
5. Water plantain (*Alisma subcordatum*). Common.
6. Wapato (*Sagittaria latifolia*). Common.
7. Cord-grass (*Spartina michauxiana*). Common.
8. Reed (*Phragmites communis*). Common.
9. Bog reedgrass (*Calamagrostis inexpansa*). Common.
10. River bulrush (*Scirpus fluviatilis*).* Common; not fruiting.
11. Spike rush (*Eleocharis palustris*). Common.
12. Willow (*Salix*). Sparse.
13. Curly dock (*Rumex crispus*). Sparse.
14. Water smartweed (*Polygonum amphibium*).* Flowers; abundant.

SUBMERGED PLANTS.

Dominant:

15. Sago pondweed (*Potamogeton pectinatus*).* Practically fills lake.

Secondary species:

16. Spike rush (*Eleocharis*, probably *acicularis*). Common.
17. Water smartweed (*Polygonum amphibium*). Common.
18. Water milfoil (*Myriophyllum spicatum*).
19. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANTS.

20. Butterflywort (*Riccia natans*). Sparse.
21. Big duckweed (*Spirodela polyrhiza*). *rhiza*).
22. Star duckweed (*Lemna trisulca*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2, 6, 10, 15, 21, and 22; those of less importance are: Nos. 3, 4, 5, 7, 11, 14 (17), 16, and 18; the remainder are of no known value.

YEARLING VALLEY LAKE, CHERRY COUNTY.

October 13, 1915.

Description.—Average greatest depth 3 to 4 feet. Bottom is sand muck. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, etc., as listed for neighboring lakes; nothing new.

SEMISUBMERGED PLANTS.

Dominant:
1. Tule (*Scirpus validus*).

Secondary species:
2. Cat-tail (*Typha latifolia*). Sparse.
3. Bur reed (*Sparganium eurycarpum*). Sparse.
4. Water plantain (*Alisma subcordatum*). Common.
5. Wapato (*Sagittaria latifolia*). Common.
6. Cord-grass (*Spartina michauxiana*). Abundant.
7. River bulrush (*Scirpus fluviatilis*). Sparse.
8. Three-square (*Scirpus americanus*). Sparse.
9. Water smartweed (*Polygonum amphibium*). Common.
10. Water hemlock (*Cicuta maculata*), and others listed under shore vegetation for neighboring lakes growing in shallow water.

SUBMERGED PLANTS.

Dominants:
11. Sago pondweed (*Potamogeton pectinatus*).
12. Water milfoil (*Myriophyllum spicatum*).

Secondary species:
13. Variable pondweed (*Potamogeton heterophyllus*).
14. Small pondweed (*Potamogeton pusillus*). Common.
15. Spike rush (*Eleocharis acicularis*). Common.
16. Water smartweed (*Polygonum amphibium*). Sparse.
17. Bladderwort (*Utricularia vulgaris*). Sparse.

FLOATING PLANTS.

18. Butterflywort (*Riccia natans*).
19. Big duckweed (*Spirodela polyrhiza*). Common.
20. Star duckweed (*Lemna trisulca*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 5, 7, 11, 13, 14, 19, and 20; those of less importance are: Nos. 3, 4, 6, 8, 9 (16), 12, and 15; the remainder are of no known value.

SILVER LAKE, CHERRY COUNTY.

October 17, 1915.

Description.—Marsh and most of the other vegetation at west end of lake; water clearer at west end of marsh than in the open where there is an alkaline appearance; bottom sandy at east half; mucky in west; average greatest depth 3 to 4 feet. Outlet to the west; since the lake is being drained, probably some current; no inlet.

Distribution of Vegetation.

SHORE PLANTS.

As for neighboring lakes.

SEMISUBMERGED PLANTS.

Dominant:
1. Tule (*Scirpus validus*).* Mature fruit, only thing growing in open water.

Secondary species:
2. Cat-tail (*Typha latifolia*).
3. Bur reed (*Sparganium eurycarpum*).
4. Water plantain (*Alisma subcordatum*).
5. Wapato (*Sagittaria latifolia*).
6. Cord-grass (*Spartina michauxiana*). Common.
7. Reed (*Phragmites communis*). Common.
8. Three-square (*Scirpus americanus*). Common.
9. Willow (*Salix*).
10. Curly dock (*Rumex crispus*). Sparse.
11. Water smartweed (*Polygonum amphibium*).
12. Water hemlock (*Cicuta maculata*). Sparse.

SUBMERGED PLANTS.

Dominant:

13. Sago pondweed (*Potamogeton pectinatus*).* The only submerged plant in open water of east half of lake.

Secondary species:

14. Floating pondweed (*Potamogeton natans*).*
15. Small pondweed (*Potamogeton pusillus*). Sparse.
16. Spike rush (*Eleocharis,* probably *acicularis*).
17. Water smartweed (*Polygonum amphibium*).
18. Water milfoil (*Myriophyllum spicatum*). Sparse.
19. Bladderwort (*Utricularia vulgaris*). Rare.

FLOATING PLANTS.

20. Big duckweed (*Spirodela polyrhiza*). Sparse.
21. Star duckweed (*Lemna trisulca*). Rare.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 5, 13, 15, 20, and 21; those of less importance are: Nos. 3, 4, 6, 8, 11, 14, 16, and 17; the remainder are of no known value.

MOFFITT LAKE, GARDEN COUNTY.

September 23, 1915.

Description.—Grazed to shore line on east side; submerged vegetation very scarce and in poor condition. Water very alkaline; average greatest depth, 5 feet; hard sand bottom. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

1. Saltgrass (*Distichlis spicata*).* Abundant.
2. Cord-grass (*Spartina gracilis*).* Mature fruit; common.
3. Wild rye (*Elymus canadensis*).* Mature fruit; common.
4. Barbed witchgrass (*Panicum barbipulvinatum*).* Immature fruit; scarce.
5. Switchgrass (*Panicum virgatum*).* Mature fruit; common.
6. Slender wheat-grass (*Agropyron tenerum*).* Mature fruit; common.
7. Three-square (*Scirpus americanus*).* Abundant.
8. Spike rush (*Eleocharis palustris*).* Common.
9. Sedge (*Carex diandra*).* Mature fruit; common.
10. Rush (*Juncus balticus*).* Common.
11. Prairie gentian (*Eustoma russellianum*).* Mature fruit; scarce.
12. Purple foxglove (*Gerardia besseyana*).* Mature fruit; sparse.
13. Ragweed (*Ambrosia elatior*).* Flowers; common.
14. Sunflower (*Helianthus annuus*).* Flowers; sparse.
15. White wreath-aster (*Aster multiflorus*).* Flowers; sparse.

SEMISUBMERGED PLANTS.

Dominant:

16. Three-square (*Scirpus americanus*).

Secondary species:

17. Cord-grass (*Spartina gracilis*).
18. Tule (*Scirpus validus*). Rare.
19. Rush (*Juncus balticus*).

SUBMERGED PLANTS.

Dominant:

20. Sago pondweed (*Potamogeton pectinatus*). The only submerged plant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 18 and 20; those of less importance are: Nos. 1, 2 (17), 4, 5, 7 (16), 8, and 9; the remainder are of no known value.

GIMLET LAKE, GARDEN COUNTY.

September 24, 1915.

Description.—Lake well filled with vegetation. Small amount of open water: average greatest depth 3½ feet; bottom mostly mucky. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

1. Arrow-grass (*Triglochin maritima*).* Mature fruit; common.
2. Switchgrass (*Panicum virgatum*). Common.
3. Barbed witchgrass (*Panicum barbipulvinatum*). Sparse.
4. Wild rye (*Elymus canadensis*). Common.
5. Cord-grass (*Spartina gracilis*). Common.
6. Saltgrass (*Distichlis spicata*). Sparse.
7. Bog reedgrass (*Calamagrostis inexpansa*). Abundant.
8. Satin grass (*Muhlenbergia foliosa*). Common.
9. Sedge (*Cyperus speciosus*). Abundant.
10. Sedge (*Carex diandra teretiuscula*). Common.
11. Sedge (*Carex haydeni*).*[1] Common.
12. Sedge (*Carex vulpinoidea*).* Flowers; sparse.
13. Rush (*Juncus balticus*). Abundant.
14. Rush (*Juncus torreyi*).* Abundant.
15. Rush (*Juncus dudleyi*).* Common.
16. Water smartweed (*Polygonum amphibium*).* Common.
17. Ragweed (*Ambrosia elatior*). Common.
18. Bur marigold (*Bidens laevis*). Common.
19. Sunflower (*Helianthus annuus*). Sparse.
20. White wreath-aster (*Aster multiflorus*). Sparse.

SEMISUBMERGED PLANTS.

Dominant:

21. Tule (*Scirpus validus*).* Mature fruit.

Secondary species:

A number of plants listed under shore vegetation grow in shallow water in addition to the following:

22. Cat-tail (*Typha latifolia*). Common.
23. Bur reed (*Sparganium eurycarpum*).
24. Water plantain (*Alisma subcordatum*). Common.
25. Wapato (*Sagittaria latifolia*). Common.
26. Cord-grass (*Spartina gracilis*).
27. Reed (*Phragmites communis*).*
28. Big bulrush (*Scirpus occidentalis*).* Scarce.
29. Water pepper (*Polygonum punctatum*). Common.
30. Water smartweed (*Polygonum amphibium*).* Flowers to mature fruit; common.
31. Curly dock (*Rumex crispus*). Sparse.
32. Water hemlock (*Cicuta maculata*).
33. Willow aster (*Aster salicifolius*). Common.

SUBMERGED PLANTS.

Dominants:

34. Sago pondweed (*Potamogeton pectinatus*).* Mature fruit.
35. Coontail (*Ceratophyllum demersum*).*

Secondary species:

36. Water moss (*Drepanocladus* sp.). Common.
37. Bushy pondweed (*Najas flexilis*). Sparse.
38. Water smartweed (*Polygonum amphibium*). Common.
39. Bladderwort (*Utricularia vulgaris*). Sparse.

FLOATING PLANTS.

40. Small duckweed (*Lemna minor*).*
41. Star duckweed (*Lemna trisulca*).* Abundant.
42. Water-meal (*Wolffia punctata*).* Abundant.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 21, 28, 34, 35, 37, 40, 41, and 42; those of less importance are: Nos. 1, 2, 3, 5 (26), 6, 9, 10, 11, 12, 16 (30, 38), 18, 23, 24, 25, and 29; the remainder are of no known value.

[1] Mr. G. P. Van Eseltine, who identified this specimen, notes that it represents an apparently undescribed form, of which he has seen specimens elsewhere, but which until named may be conveniently classed with its nearest relative, *haydeni*.

CRESCENT LAKE, GARDEN COUNTY.

September 26, 1915.

Description.—Grazed to shore line on east and south sides. Mostly open water, probably somewhat alkaline; average greatest depth 10 to 11 feet; bottom sandy. No current except that caused by wind. Inlet from lake at southwest end.

Distribution of Vegetation.

SHORE PLANTS.

About as for Gimlet Lake; in addition, the following:

1. Redtop (*Agrostis alba*).*
2. Straw sedge (*Cyperus strigosus*).* Mature fruit; common.
3. Sedge (*Cyperus schweinitzii*).* Mature fruit.
4. Water hoarhound (*Lycopus americanus*).* Mature fruit; common.
5. Blue verbena (*Verbena hastata*).* Mature fruit.
6. Willow aster (*Aster salicifolius*).* Flowers.

SEMISUBMERGED PLANTS.

Dominant:

7. Tule (*Scirpus validus*).

Secondary species:

8. Cat-tail (*Typha latifolia*).
9. Bur reed (*Sparganium eurycarpum*). Common.
10. Water plantain (*Alisma subcordatum*). Common.
11. Wapato (*Sagittaria latifolia*). Common.

Also, some of the shore plants growing in shallow water, as:

12. Arrow-grass (*Triglochin maritima*).
13. Wild millet (*Echinochloa crus-galli*). Common.
14. Reed (*Phragmites communis*). Common.
15. Cordgrass (*Spartina gracilis*). Common.
16. Bog reedgrass (*Calamagrostis inexpansa*).
17. Rush (*Juncus balticus*).
18. Rush (*Juncus dudleyi*).
19. Rush (*Juncus torreyi*).
20. Water smartweed (*Polygonum amphibium*).
21. Water hemlock (*Cicuta maculata*). Sparse.

SUBMERGED PLANTS.

Dominant:

22. Sago pondweed (*Potamogeton pectinatus*).

Secondary species:

23. Curly pondweed (*Potamogeton perfoliatus richardsonii*).* Immature fruit; rare.
24. Water smartweed (*Polygonum amphibium*).

FLOATING PLANTS.

25. Butterflywort (*Riccia natans*).*
26. Small duckweed (*Lemna minor*).
27. Star duckweed (*Lemna trisulca*).
28. Water-meal (*Wolffia punctata*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 7, 11, 22, 26, and 27; those of less importance are: Nos. 2, 3, 9, 10, 12, 13, 15, 20 (24), 23, and 28; the remainder are of no known value.

BEAVER (OR BLUE) LAKE, GARDEN COUNTY.

September 27–28, 1915.

Description.—Practically all open water; probably somewhat alkaline; average greatest depth 15 to 16 feet; bottom sandy. Inlet from Jones Lake; outlet into Crescent Lake; probably some current flowing east.

Distribution of Vegetation.

SHORE PLANTS.

About as for Crescent Lake, in addition the following:

1. Wild millet (*Echinochloa crus-galli*).* Mature fruit; common.
2. Rice cut-grass (*Homalocenchrus oryzoides*).* Immature fruit; sparse.
3. Spike rush (*Eleocharis,* probably *glaucescens*).* Abundant.
4. Heart's-ease (*Polygonum pennsylvanicum*).* Mature fruit.
5. Bushy knotweed (*Polygonum ramosissimum*).* Mature fruit; sparse.
6. Western chokecherry (*Padus melanocarpa*).* Rare.
7. Touch-me-not (*Impatiens biflora*).* Mature fruit; sparse.
8. Willow herb (*Epilobium lineare*).* Mature fruit; common.
9. Water hoarhound (*Lycopus asper*).* Mature fruit; common.
10. Black nightshade (*Solanum nigrum*).* Mature fruit; rare.
11. Bushy goldenrod (*Euthamia graminifolia*).* Flowers; common.
12. Sunflower (*Helianthus annuus*).* Flowers.
13. Bur marigold (*Bidens laevis*).* Flowers.

SEMISUBMERGED PLANTS.

Dominant:

14. Tule (*Scirpus validus*).

Secondary species:

15. Cat-tail (*Typha latifolia*). Sparse.
16. Water plantain (*Alisma subcordatum*). Common.
17. Reed (*Phragmites communis*).
18. Cord-grass (*Spartina gracilis*).
19. Three-square (*Scirpus americanus*).
20. Spike rush (*Eleocharis,* probably *glaucescens*). Common.
21. Water hemlock (*Cicuta maculata*). Sparse.

SUBMERGED PLANTS.

Dominant:

22. Sago pondweed (*Potamogeton pectinatus*).

Secondary species:

23. Spike rush (*Eleocharis,* probably *glaucescens*).

FLOATING PLANTS.

24. Star duckweed (*Lemna trisulca*). Not common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 14, 22, and 24; those of less importance are: Nos. 1, 2, 3, 4, 13, 16, 18, 19, and 20 (23); the remainder are of no known value.

JONES LAKE, GARDEN COUNTY.

September 27–28, 1915.

Description.—Bottom sandy; depth, 6 to 8 feet. Inlet from Swan Lake; outlet into Blue Lake.

Distribution of Vegetation.

SHORE PLANTS.

About as for Crescent Lake; in addition the following:

1. Wild millet (*Echinochloa crus-galli*). Common.
2. Rice cut-grass (*Homalocenchrus oryzoides*). Sparse.
3. Redtop (*Agrostis alba*).
4. Straw sedge (*Cyperus strigosus*). Common.
5. Sedge (*Cyperus schweinitzii*).
6. Spike rush (*Eleocharis,* probably *glaucescens*). Abundant.
7. Bushy knotweed (*Polygonum ramosissimum*). Sparse.
8. Heart's-ease (*Polygonum pennsylvanicum*). Common.
9. Western chokecherry (*Padus melanocarpa*). Rare.
10. Touch-me-not (*Impatiens biflora*). Sparse.
11. Willow herb (*Epilobium lineare*). Common.
12. Blue verbena (*Verbena hastata*).
13. Water hoarhound (*Lycopus americanus*). Common.
14. Water hoarhound (*Lycopus asper*). Common.
15. Black nightshade (*Solanum nigrum*). Rare.
16. Bushy goldenrod (*Euthamia graminifolia*). Common.
17. Sunflower (*Helianthus annuus*).
18. Bur marigold (*Bidens laevis*).
19. Willow aster (*Aster salicifolius*).

SEMISUBMERGED PLANTS.

Dominant:
20. Tule (*Scirpus validus*).

Secondary species:
21. Cat-tail (*Typha latifolia*).
22. Bur reed (*Sparganium eurycarpum*).
23. Wapato (*Sagittaria latifolia*).
24. Reed (*Phragmites communis*).
25. Cord-grass (*Spartina gracilis*).
26. Three-square (*Scirpus americanus*).
27. Spike rush (*Eleocharis,* probably *glaucescens*).
28. Water smartweed (*Polygonum amphibium*).
29. Water hemlock (*Cicuta maculata*).

SUBMERGED PLANTS.

Dominant:
30. Sago pondweed (*Potamogeton pectinatus*).

Secondary species:
31. Spike rush (*Elepcharis,* probably *glaucescens*).
32. Water smartweed (*Polygonum amphibium*).
33. Bladderwort (*Utricularia vulgaris*).

FLOATING PLANTS.

34. Small duckweed (*Lemna minor*).
35. Star duckweed (*Lemna trisulca*). Abundant.
36. Water-meal (*Wolffia punctata*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are Nos. 20, 23, 30, 34, and 35; those of less importance are Nos. 1, 2, 4, 5, 6 (27, 31), 8, 18, 22, 25, 26, 28 (32), and 36; the remainder are of no known value.

SWAN LAKE, GARDEN COUNTY.

September 27–28, 1915.

Description.—Grazed to water's edge. Water probably alkaline; depth, 8 to 10 feet; bottom sandy. No inlet; outlet into Jones Lake.

Description of Vegetation.

SHORE PLANTS.

About as for Crescent Lake; in addition the following:

1. Wild millet (*Echinochloa crus-galli*). Common.
2. Rice cut-grass (*Homalocenchrus oryzoides*). Sparse.
3. Spike rush (*Eleocharis,* probably *glaucescens*). Abundant.
4. Bushy knotweed (*Polygonum ramosissimum*). Sparse.
5. Heart's-ease (*Polygonum pennsylvanicum*). Common.
6. Western chokecherry (*Padus melanocarpa*). Rare.
7. Wild bean (*Strophostyles pauciflora*).* Mature fruit.
8. Touch-me-not (*Impatiens biflora*). Sparse.
9. Willow herb (*Epilobium lineare*). Common.
10. Water hoarhound (*Lycopus asper*). Common.
11. Black nightshade (*Solanum nigrum*). Rare.
12. Bushy goldenrod (*Euthamia graminifolia*). Common.
13. Sunflower (*Helianthus annuus*).
14. Bur marigold (*Bidens laevis*).

SEMISUBMERGED PLANTS.

Dominant:
15. Tule (*Scirpus validus*).

Secondary species:
16. Cat-tail (*Typha latifolia*).
17. Bur reed (*Sparganium eurycarpum*).
18. Cord-grass (*Spartina gracilis*).
19. Spike rush (*Eleocharis,* probably *glaucescens*).
20. Water smartweed (*Polygonum amphibium*).

SUBMERGED PLANTS.

Dominant:
21. Sago pondweed (*Potamogeton pectinatus*).

Secondary species:
22. Curly pondweed (*Potamogeton perfoliatus richardsonii*). Sparse.
23. Spike rush (*Eleocharis,* probably *glaucescens*).

FLOATING PLANTS.

24. Small pondweed (*Lemna minor*).
25. Star duckweed (*Lemna trisulca*).
26. Water-meal (*Wolffia punctata*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 15, 21, 24, and 25; those of less importance are: Nos. 1, 2, 3 (19, 23), 5, 17, 18, 20, 22, and 26; the remainder are of no known value.

RENO LAKE, GARDEN COUNTY.

September 29, 1915.

Description.—Marsh on north side. Water 4 to 5 feet deep; bottom mostly sandy; muck bottom in marsh. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, sedges, etc., as listed for neighboring lakes; grazed to shore line on south side.

SEMISUBMERGED PLANTS.

Dominant:
1. Tule (*Scirpus validus*).

Secondary species:
2. Cat-tail (*Typha latifolia*). Common.
3. Bur reed (*Sparganium eurycarpum*).
4. Wapato (*Sagittaria latifolia*). Common.
5. Cord-grass (*Spartina gracilis*). Common.
6. Reed (*Phragmites communis*). Common.
7. Three-square (*Scirpus americanus*). Common.
8. Big bulrush (*Scirpus occidentalis*). Rare.
9. Spike rush (*Eleocharis,* probably *glaucescens*). Abundant.
10. Water smartweed (*Polygonum amphibium*).
11. Water hemlock (*Cicuta maculata*).

SUPMERGED PLANTS.

Dominant:
12. Sago pondweed (*Potamogeton pectinatus*).* Mature fruit.

Secondary species:
13. Small pondweed (*Potamogeton pusillus*). Common.
14. Widgeon grass (*Ruppia occidentalis*).*
15. Spike rush (*Eleocharis acicularis*).
16. Spike rush (*Eleocharis,* probably *glaucescens*).
17. Water smartweed (*Polygonum amphibium*). Common.
18. Bladderwort (*Utricularia vulgaris*). Common.

FLOATING PLANT.

19. Star duckweed (*Lemna trisulca*).*

Wild-duck foods.—Plants in the above list which have considerable value as food for wild-ducks are: Nos. 1, 4, 8, 12, 13, 14, and 19; those of less importance are: Nos. 3, 5, 7, 9 (16), 10 (17), and 15; the remainder are of no known value.

TRAINOR LAKES, GARDEN COUNTY.

September 30, 1915.

Description.—North Trainor Lake, small; South Trainor Lake, about half open water; the two connect by a small stream. Fresh water; bottom mostly sandy; mucky in part of marsh area; average greatest depth, 3 to 4 feet.

Distribution of Vegetation.

SHORE PLANTS.

Typical meadow of grasses, sedges, rushes, mints, etc., as listed for neighboring lakes.

SEMISUBMERGED PLANTS.

Dominant:

1. Tule (*Scirpus validus*).

Secondary species:

2. Horsetail (*Equisetum* sp.)
3. Cat-tail (*Typha latifolia*). Common.
4. Bur reed (*Sparganium eurycarpum*). Sparse.
5. Water plantain (*Alisma subcordatum*). Common.
6. Wapato (*Sagittaria latifolia*). Common.
7. Cord-grass (*Spartina gracilis*). Common.
8. Reed (*Phragmites communis*). Common.
9. Three-square (*Scirpus americanus*). Common.
10. Spike rush (*Eleocharis acicularis*).
11. Spike rush (*Eleocharis*, probably *glaucescens*).
12. Sedge (*Carex utriculata*).*
13. Water smartweed (*Polygonum amphibium*).
14. Water hemlock (*Cicuta maculata*). Rare.

–. Other grasses, etc., of shore, growing in shallow water.

SUBMERGED PLANTS.

Dominants:

15. Sago pondweed (*Potamogeton pectinatus*).
16. Bladderwort (*Utricularia vulgaris*).* With winter buds.

Secondary species:

17. Musk grass (*Chara* sp.).* Common.
18. Small pondweed (*Potamogeton pusillus*).* Winter buds; common.
19. Widgeon grass (*Ruppia occidentalis*).* Common.
20. Spike rush (*Eleocharis acicularis*).* Common.
21. Spike rush (*Eleocharis*, probably *glaucescens*).
22. Water smartweed (*Polygonum amphibium*). Common.

FLOATING PLANTS.

23. Small duckweed (*Lemna minor*). Common.
24. Star duckweed (*Lemna trisulca*). Common.
25. Water-meal (*Wolffia punctata*). Common.

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 1, 6, 15, 17, 18, 19, 23, and 24; those of less importance are: Nos. 4, 5, 7, 9, 10 (20), 11 (21), 12, 13 (22), and 25; the remainder are of no known value.

PETERSON LAKE NO. 1, GARDEN COUNTY.

October 2, 1915.

Description.—Bottom mucky; average greatest depth, 2 feet. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, etc., as listed for neighboring lakes.

SEMISUBMERGED PLANTS.

Dominant:
1. Tule (*Scirpus validus*).

Secondary species:
2. Cat-tail (*Typha latifolia*).
3. Bur reed (*Sparganium eurycarpum*).
4. Water plantain (*Alisma subcordatum*).
5. Wapato (*Sagittaria latifolia*).
6. Cord-grass (*Spartina gracilis*).
7. Reed (*Phragmites communis*). Common.
8. Three-square (*Scirpus americanus*).
9. Water smartweed (*Polygonum amphibium*). Common.
10. Water hemlock (*Cicuta maculata*).

SUBMERGED PLANTS.

11. Musk grass (*Chara* sp.).
12. Sago pondweed (*Potamogeton pectinatus*).
13. Small pondweed (*Potamogeton pusillus*).
14. Spike rush (*Eleocharis acicularis*).
15. Spike rush (*Eleocharis*, probably *glaucescens*).
16. Water smartweed (*Polygonum amphibium*).
17. White water crowfoot (*Batrachium divaricatum*).* Common.
18. Bladderwort (*Utricularia vulgaris*).

FLOATING PLANTS.

19. Star duckweed (*Lemna trisulca*). Very abundant.
20. Small duckweed (*Lemna minor*).
21. Water-meal (*Wolffia punctata*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are Nos. 1, 5, 11, 12, 13, 19, and 20; those of less importance are: Nos. 3, 4, 6, 8, 9 (16), 14, 15, 17, and 21; the remainder are of no known value.

PETERSON LAKE NO. 2, GARDEN COUNTY.

October 2, 1915.

Description.—Bottom mucky; average depth 4 feet. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

Grasses, etc., as listed for neighboring lakes; in addition the following:
1. Spider flower (*Cleome serrulata*).* Mature fruit.

SEMISUBMERGED PLANTS.

Dominant:
2. Tule (*Scirpus validus*).

Secondary species:
3. Three-square (*Scirpus americanus*).

SUBMERGED PLANTS.

Dominant:
4. Widgeon grass (*Ruppia occidentalis*).* Immature fruit; practically fills lake, which was covered with ducks apparently feeding on this plant.

Secondary species:
5. Sago pondweed (*Potamogeton pectinatus*).

Wild-duck foods.—Plants in the above list which have considerable value as food for wild ducks are: Nos. 2, 4, and 5; one of less importance is 3; the remaining one is of no known value.

PHALAROPE LAKE, GARDEN COUNTY.

October 3, 1915.

Description.—Alkaline water; average greatest depth, 3 feet; bottom sandy. No inlet or outlet.

Distribution of Vegetation.

SHORE PLANTS.

About as for Moffitt Lake.

SEMISUBMERGED PLANT.

Dominant:

1. Three-square (*Scirpus americanus*). The only one.

SUBMERGDD PLANT.

2. Sago pondweed (*Potamogeton pectinatus*). The only plant growing submerged.

Wild-duck foods.—Both plants in the above list have considerable value as food for wild ducks.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 795

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C. PROFESSIONAL PAPER July 28, 1919

THE ADULTERATION OF INSECT POWDER WITH POWDERED DAISY FLOWERS (CHRYSANTHEMUM LEUCANTHEMUM L.).

By R. C. Roark, *Assistant Chemist for the Insecticide and Fungicide Board, Insecticide and Fungicide Laboratory, Miscellaneous Division*, and G. L. Keenan, *Microanalyst for the Insecticide and Fungicide Board, Microchemical Laboratory.*

CONTENTS.

ADULTERATION OF INSECT POWDER.

Almost from the time that it first appeared as an article of commerce, insect powder has been subjected to adulteration with a great variety of substances. Flowers of other plants of the family Compositæ naturally suggested themselves for this purpose, particularly those of the genus Chrysanthemum, to which the three species of genuine insect flowers[1] belong. Of all the species of Chrysanthemum, *C. Leucanthemum* probably has been one of those most often utilized for the sophistication of insect powder, and in the course of the examination of commercial insect powders for the Insecticide and Fungicide Board, its presence has been frequently detected. This plant, popularly known as "ox-eye daisy," "field daisy," "white weed," and

[1] "Insect powder" consists of the powdered flower heads of any of the following species of Chrysanthemum: (1) *Chrysanthemum* (*Pyrethrum*) *cinerariæfolium* (Trev.) Bocc.; (2) *Chrysanthemum* (*Pyrethrum*) *roseum* Web and Mohr.; (3) *Chrysanthemum Marshallii* Aschers (synonym, *Pyrethrum carneum* M. B.) (Insecticide Decision 1, Insecticide and Fungicide Board, U. S. Department of Agriculture, August 26, 1911). At the present time all of the insect powder obtained in the United States is of the first named species.

"marguerite," occurs as a common weed in many parts of the United States, and is also found abundantly in those regions in Europe where the Dalmatian insect flowers *(C. cinerariæfolium)* grow. Its cheapness and ready availability have favored its use as an adulterant. The flowers have been the only part of the plant used for this purpose. These flowers, a regular article of commerce with the collectors of crude drugs in certain parts of the southern United States, are gathered by people living in the mountainous districts, who dry them, and then deliver them to country storekeepers in exchange for merchandise. When the storekeeper has accumulated a sufficient stock of "medicinal" roots, herbs, barks, flowers, etc., he takes them into town where he sells them to a dealer in these commodities. Occasionally a small lot may be sent directly by parcel post or express to the drug dealer by the original collector, but the usual channel is through the country storekeepers. The daisy flowers, as received by the drug dealers, are remarkably free from other plant material, and the amount of adhering stalk is negligible, an occasional corncob or chicken feather being practically the only extraneous material found with the flowers.

A review of the literature shows that this species of Chrysanthemum has long been recognized as an adulterant of insect powder. Beringer (2),[1] Schrenk (29), and Unger (36) were the first to report the use of these flowers for this purpose. Others who include daisy flowers in the list of common adulterants of insect powder are Cæsar and Loretz (4), Huber (17), Verneau (38), Tschirch and Oesterle (35), Durrant (11), Hockauf (16), and Hanausek and Winton (15). Siedler (31) states that the flowers of *C. Leucanthemum* have been exported from Dalmatia for several years under the name "False Insect Flowers."

USES FOR CHRYSANTHEMUM LEUCANTHEMUM.

Schoepf (28), La Tourrette (19), Shecut (30), Rafinesque (25), Williams (40), Stearns (32), and Dragendorff (9) describe certain medicinal uses for *Chrysanthemum Leucanthemum.* According to Cutler (7) and Shecut (30), the young leaves have been employed in salads. Merat and De Lens (21) of France and Porcher (24) of the United States state that no use is made of the plant in these countries. Stearns (32), however, states that the flowers were used in medicine by the natives of Michigan in the early fifties.

According to the United States Dispensatory (37), German chamomile *(Matricaria chamomilla* L.) is sometimes adulterated with the flower heads of the common daisy, and Griffith (14) lists it as an adulterant or substitute for chamomile *(Anthemis nobilis* L.). Through an investigation of the subject in 1918, the writers learned that ox-

[1]The numbers refer to the bibliography, page 11.

eye daisy flowers are used to a very limited extent in some of the New England States in the preparation of a "tea" for "medicinal" purposes. It is quite evident, however, that the daisy flowers collected in this country are used largely, if not exclusively, as an adulterant of insect powder.

INSECTICIDAL ACTION OF CHRYSANTHEMUM LEUCANTHEMUM.

Cantraine (5) learned in Ragusa that the Bosnians and Dalmatians used the *C. Leucanthemum* to destroy fleas, but fails to state what part of the plant served this purpose. It is quite probable that Cantraine mistook the flowers of *C. cinerariæfolium* for those of *C. Leucanthemum* because of their similarity. Garrigues (12) quotes Cantraine and an unnamed writer who states that the flowers, dried, pulverized, and used as the *Pyrethrum caucasicum*, have the power of destroying insects. An anonymous writer in the Gardeners' Chronicle (1) states that the Spaniards burn the centers of these flowers in order to keep gnats away.

Kalbruner (18), Beringer (2), Cæsar and Loretz (3), Huber (17), and Riley (27) found powdered daisy flowers to be inactive as an insecticide. Scott and Abbott, of the Bureau of Entomology, U. S. Department of Agriculture, have recently tested powdered daisy flowers against roaches, bedbugs, house flies, cabbage aphis, chrysanthemum aphis, nasturtium aphis, orthezia, and red spider, finding it to be inactive in every case.

The use of daisy flowers in insect powder is for no other purpose than to cheapen it. Since this form of adulteration is being carried on to a marked extent at the present time, it was deemed necessary to make a special study of this subject, with the view of establishing methods for its detection and quantitative estimation. Samples of the flowers of *C. Leucanthemum* were collected for this purpose from various sources, mainly from the collectors of "medicinal" herbs in the mountainous regions of Virginia and North Carolina.

CHEMISTRY OF CHRYSANTHEMUM LEUCANTHEMUM.

More or less complete analyses of *C. Leucanthemum* have been made by Goessmann (13), Millspaugh (22), Stone (33), Penny (23), Beringer (2), Thoms (34), and Dietze (8). The results obtained by them are given in Table 1.

TABLE 1.—*Analyses of Chrysanthemum Leucanthemum L.*

Analyst	Source of sample	Part of plant	[1]Moisture	[2]Nitrogen, N	Ash	Fat (ether extract)	Crude fiber	Phosphorus pentoxid, P_2O_5	Potassium oxid, K_2O	Manganese, Mn	Water extract	Alcohol extract	Petroleum-ether extract
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Goessmann	Mass.	Whole plant.	9.65	1.36	7.80	2.57	39.94	.....	.....	.....	.....	.....	.....
Millspaugh	W. Va.	do	.....	2.12	.....	.....	.....	0.45	2.88	.....	.....	.....	.....
Stone	N. H.	do	77.50	1.36	8.40	2.53	28.89	.....	.....	.....	.....	.....	.....
Penny	Del.	do	70.89	1.29	7.08	4.99	28.16	.....	.....	.....	.....	.....	.....
Beringer	(?)	Flowers only	.....	.....	9.30	2.68	.....	.....	.....	.....	13.43	9.45	3.37
Thoms	(?)	do	10.11	.....	8.93	.....	.....	.....	.....	Pres.	.....	.....	.....
Dietze	(?)	do	7.59	.....	8.90	[3]3.76 [4]3.17	.....	.....	.....	.....	.....	.....	[5]2.46 [6]2.25

[1]In those cases in which moisture is reported, the results for the other constituents are calculated on a moisture-free basis.
[2]Protein divided by 6.25.
[3]Ether of specific gravity 0.735 used.
[4]Ether of specific gravity 0.720 used.
[5]Petroleum ether used.
[6]"Purest" petroleum ether used.

In Table 2 are presented the results of analyses of the samples collected by the authors and obtained from drug collectors in Virginia and North Carolina during the summer of 1917. The analyses were made according to the methods of the Association of Official Agricultural Chemists (Jour. A. O. A. C., vol. 2, no. 1, pt. 2, May 15, 1916).

TABLE 2.—*Analyses of ox-eye daisy flowers (Chrysanthemum Leucanthemum L.).*[1]

Laboratory No.	Place collected	Date collected	Moisture	Nitrogen, N	Ash	Ash insol. in HCl	Crude fiber	Pentosans	Ether extract	Petroleum-ether extract	Phosphorus pentoxid, P_2O_5	Manganese, Mn
			Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
28242	Southwestern Virginia	July, 1917	6.03	1.81	9.60	0.66	23.17	13.29	5.16	3.66	0.85	0.0087
28243	do	do	6.95	1.80	9.20	.42	21.70	.....	5.31	3.82	.....	.0098
28244	do	do	5.53	1.87	9.68	.48	23.49	.....	4.59	3.30	.....	.0093
28245	do	do	6.78	1.91	10.12	1.20	22.03	11.97	4.87	3.46	.85	.0104
28246	do	do	6.98	1.80	9.10	.30	22.38	.....	5.47	3.63	.....	.0096
28247	do	do	6.25	1.86	9.06	.38	23.37	.....	4.93	3.71	.....	.0082
28248	do	do	7.15	1.95	9.60	.90	22.56	.....	4.90	3.32	.....	.0111
28249	do	do	6.45	1.93	9.90	.60	22.40	.....	5.53	3.58	.....	.0101
28250	do	do	7.18	1.94	9.44	.78	22.69	12.41	4.91	3.09	.86	.0090
28251	do	do	6.60	1.84	9.86	.88	24.09	.....	5.53	3.85	.....	.0083
28252	do	do	6.88	1.90	9.46	.84	22.98	.....	4.96	3.66	.....	.0096
28253	do	do	4.83	1.83	9.54	.44	22.47	.....	4.80	3.62	.....	.0086
28256	Western North Carolina	June, 1917	4.30	1.93	9.36	.58	22.63	12.95	4.02	3.18	.69	.0113
28257	do	July, 1917	4.58	1.79	12.49	2.84	22.45	11.63	4.83	3.34	.81	.0079
28258	do	Aug., 1917	5.18	1.82	11.70	2.52	24.23	12.10	5.52	3.54	.88	.0072
28396	Buncombe Co., N. C.	do	8.25	2.07	10.74	1.85	22.75	11.83	5.11	3.51	.93	.0110
28397	do	do	8.09	1.66	9.90	1.26	21.04	11.99	5.33	3.50	.98	.0083
28398	Yancey Co., N. C.	July, 1917	7.62	1.77	12.68	3.04	22.63	11.80	5.34	3.80	.81	.0102
28399	do	do	7.92	1.62	9.38	.46	21.93	12.67	6.27	4.46	.88	.0083
14933	Not known	.....	.....	1.82	10.02	.92	20.14	14.34	3.18	.....	.68	.....
23020	Markham, Va.	July, 1915	.....	2.23	10.45	.15	.....	.....	.....	.....	.....	.....
	Minimum	.....	4.30	1.62	9.06	.15	20.14	11.63	3.18	3.09	.68	.0072
	Maximum	.....	8.25	2.23	12.68	3.04	24.23	14.34	6.27	4.46	.98	.0113
	Average	.....	6.50	1.86	10.06	1.02	22.56	12.45	5.03	3.58	.84	.0093

[1]J. J. T. Graham, Assistant Chemist, Insecticide and Fungicide Laboratory, assisted in making the analyses reported in this table.

TABLE 3.—*Comparison of average analyses of C. cinerariæfolium and C. Leucanthemum L.*[1]

Sample	Moisture[2]	Nitrogen,[2] N	Ash[2]	Ash insol. in HCl[2]	Crude fiber[2]	Pentosans[2]	Ether extract[2]	Petroleum-ether extract[2]	Phosphorus pentoxid,[2] P_2O_5	Manganese,[2] Mn
C. cinerariæfolium:	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Closed flowers	.....	1.784 (103)	7.20 (103)	0.49 (103)	22.09 (27)	16.66 (5)	6.87 (6)	4.11 (5)	0.691 (34)	0.0120 (22)[3]
Open flowers	6.69 (17)	1.267 (104)	6.09 (104)	.26 (104)	31.02 (28)	21.11 (5)	5.81 (8)	4.06 (8)	.532 (94)	.0096 (13)[3]
Stems	.....	.765 (73)	4.90 (38)	.50 (38)	40.66 (27)	18.21 (5)	3.22 (7)	1.97 (7)	.234 (38)	.0100 (22)[3]
C. Leucanthemum:										
Flowers	6.50 (19)	1.86 (21)	10.06 (21)	1.02 (21)	22.56 (20)	12.45 (11)	5.03 (20)	3.58 (19)	.84 (11)	.0093 (19)

[1]These results, except those for manganese, are taken from an unpublished paper, "Insect Powder," by McDonnell, Roark, and Keenan.
[2]The numbers in parentheses indicate the number of samples upon which the determination in question was made.
[3]"Manganese in Insect Flowers and Insect Flower Stems," Journal of Agricultural Research, *11:* 81. 1917.

Table 3 gives a comparison of analyses of the different commercial grades of insect flowers ("open" and "closed") and insect flower stems with those of the flowers of *C. Leucanthemum*. The averages of all determinations are compared for each constituent.

The results in Table 3 show that the greatest differences in the chemical composition are in the phosphorus, ash, and pentosans, which are higher in the flowers of *C. Leucanthemum* than in those of *C. cinerariæfolium*. It is evident, however, that a chemical analysis alone is insufficient to show adulteration of insect powder with powdered daisy flowers. Such adulteration can be definitely determined only by microscopic examination.

MORPHOLOGY OF CHRYSANTHEMUM LEUCANTHEMUM.

The daisy plant is a typical Composite. It is a perennial with nearly smooth stem, growing to a height of from 1 to 3 feet, and sparingly branched. The leaves are coarsely cut, the uppermost leaves being smaller than the lower ones and nearly entire. The flower heads consist of white ray flowers and yellow disc flowers. The involucral bracts are lanceolate, nearly smooth, with a narrow, chestnut-brown margin. The fruit, when mature, consists of very small achenes, with a black background and conspicuous white ribs running lengthwise of the fruit. There is usually a small tubercle or knob-like projection on the broad end, apparently the remains of the flowers. (Pl. I, fig. 2.)

Beringer (2) and Vogtherr (39) go quite into detail in a morphological description of field daisy flowers.

Field daisy flowers occurring in insect flowers are much more easily detected than when in powdered form. The most positive character that can be relied upon for their detection is the fruit. Even in an immature condition the fruit of the daisy does not resemble that of *Chrysanthemum cinerariæfolium*. The following compilation is given to serve as an aid in distinguishing between the fruits of *C. cinerariæfolium* and those of *C. Leucanthemum* (Pl. I, figs. 1 and 2).

Dalmatian flowers.—Achenes 5-ribbed; possess small-toothed crown; golden yellow in color; ray floret achenes more curved or arched than the disc floret achenes (Pl. I, fig. 1).

Daisy flowers.—Achenes usually 10-ribbed; ribs very prominent, white, alternating with black stripes; tubercle or knob-like projections on broad end of achene; achene much smaller than that of the Dalmatian flower (Pl. I, fig. 2).

HISTOLOGY.

Schrenk (29) claims to have found a positively characteristic structure of daisy powder in the small, several-celled hairs which he detected in considerable numbers on the apparently glabrous scales

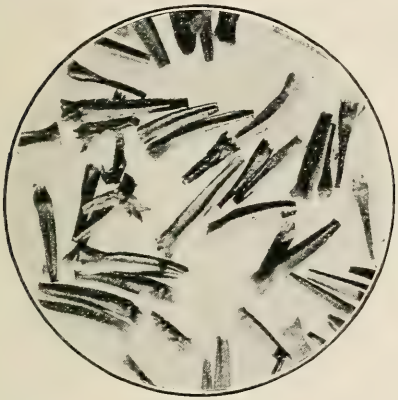

FIG. 1.—Achenes, Dalmatian flowers (×3).

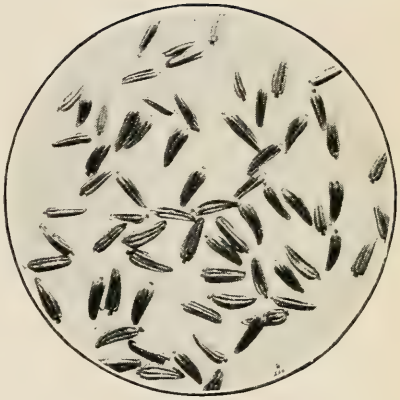

FIG. 2.—Achenes, daisy flowers (×3).

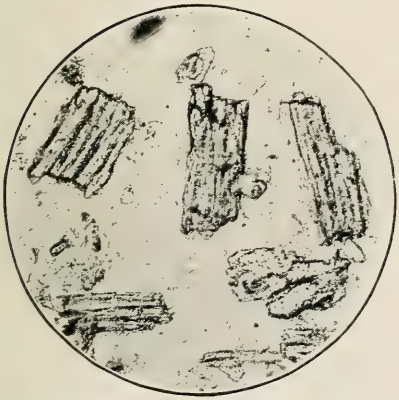

FIG. 3.—Achene tissue, Dalmatian flowers (×130).

FIG. 4.—Achene tissue, daisy flowers (×240).

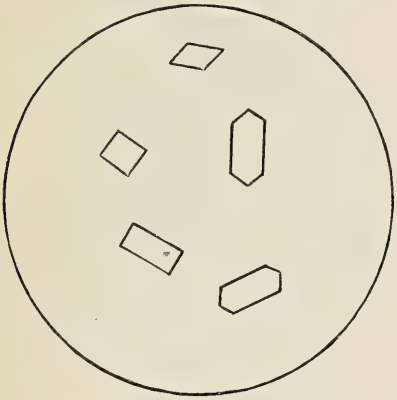

FIG. 1.—Crystals from achenes, Dalmatian flowers (magnified).

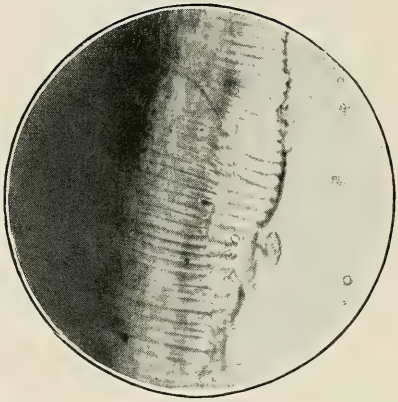

FIG. 2.—Achene tissue, daisy flowers (×180).

FIG. 3.—Stalked hair, Dalmatian flowers (magnified).

FIG. 4.—Hairs, daisy flowers (×350).

(Pl. II, fig. 4). Durrant (10) found difficulty in detecting daisy in genuine insect powder, and Beringer (2) could detect no difference microscopically between the two powders.

However easily the hairs Schrenk has referred to may be detected on the unground involucral scales, their presence is very difficult to establish when the scales are powdered. Apparently the hairs are very fragile and become readily broken up in the process of grinding.

The achenes of *Chrysanthemum cinerariæfolium* and *Chrysanthemum Leucanthemum* are strikingly different in the powdered form. The achene tissues of the Dalmatian flowers *(C. cinerariæfolium)* are characterized by the numerous crystals, which exhibit a variety of colors under polarized light. On the other hand, the achene tissues of the daisy flowers *(C. Leucanthemum)* exhibit no such crystals, but contain a notable amount of a brownish-red material, the location of which is readily demonstrated in a cross-section of the fruit. In a cross-section of the achene, crescent-shaped structures, corresponding to each of the ten ribs, stand out very distinctly (fig. 1).

When the daisy flower heads are powdered, this brownish-red material contained in the crescent-shaped structures breaks up into irregular, angular fragments, sometimes attached to the surrounding tissues, and sometimes separated from them. These fragments assume a deep, brownish-red color when the powder is heated in a solution of chloral hydrate in water about 1:1.

Aside from this dark brown material, a portion of the tissue from the white ribs of the daisy achene is another diagnostic character. The outer portion of the rib consists, in radial section, of what are apparently epidermal cells. They appear to have a palisade-like arrangement, consisting of narrow, thick-walled cells packed very closely together (Pl. II, fig. 2). This tissue, which invariably occurs in the daisy powder in the form of radial sections, serves as another means for detecting its presence in genuine insect powder.

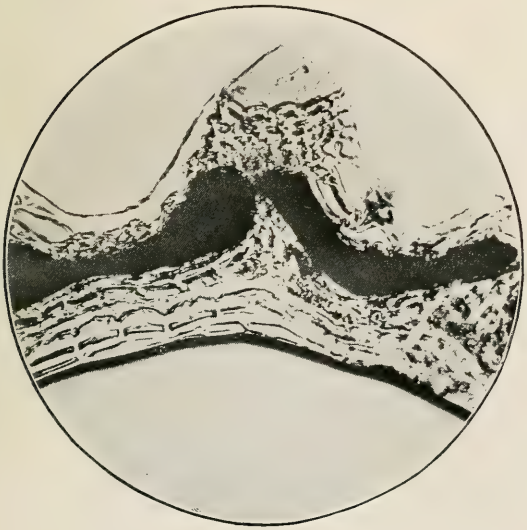

FIG. 1.—Cross-section of daisy achene (illustrating crescent-shaped structures).

Experience gained in the comparative study of a large number of samples ground from insect flow-

ers and from daisy flowers has emphasized the need for caution in placing reliance upon any histological characters in the daisy flowers other than those of the achene. Other characters, with the exception of the T-shaped hairs of the Dalmatian flowers (Pl. II, fig. 3) and the crystal-bearing stone cells of the achene, are too nearly like similar characters in insect flowers. While these hairs and crystal-bearing stone cells of the achene would furnish a means of identifying Dalmatian flowers in a mixture with other materials, they very apparently offer no means of discovering the presence of the daisy flowers when mixed with Dalmatian flowers. Thus the presence of this brownish-red material (Pl. I, fig. 4) and the palisade-like epidermal cells (Pl. II, fig. 2) furnishes a reliable means of detecting even small quantities of daisy flowers in a mixture.

No attempt has been made to describe the other parts of the daisy flower in detail, the scope of this paper being limited to those differentiating tissue elements which might be readily detected in an insect powder adulterated with powdered daisy flowers. A brief description of the diagnostic tissues of the achenes of the Dalmatian flower *(C. cinerariafolium)* and of the daisy flower *(C. Leucanthemum)* follows:

Dalmatian flower achene.—Characterized in the powder by rectangular patches of hard sclerenchyma tissues, strongly lignified and possessing numerous clinorhombic crystals which exhibit a great variety of colors under polarized light. In older flowers (open flowers) isolated stone cells are very common (Pl. I, fig. 3; Pl. II, fig. 1).

Daisy flower achene.—Characterized in the powder by irregular dark-red fragments of variable size exhibiting a very deep-red color when the powder, after heating in chloral hydrate solution (about 1:1), is examined under the microscope; also by closely-packed palisade-like tissue with thick walls and narrow lumina, usually present in radial section in the powder (Pl. I, fig. 4; Pl. II, fig. 2).

SUMMARY.

While there are certain differences in the chemical composition of *Chrysanthemum cinerariafolium* and *Chrysanthemum Leucanthemum*, a chemical analysis is insufficient to show adulteration of insect powder with daisy flowers.

Adulteration of insect powder with powdered daisy flowers can be definitely determined by microscopic examination. Powdered daisy flowers are distinguished by (a) the irregular dark-red fragments of the achene, and (b) the palisade-like cells comprising the costal tissue of the achene.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 796

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

Washington, D. C. October 21, 1919

USE OF TOXIC GASES AS A POSSIBLE MEANS OF CONTROL OF THE PEACH-TREE BORER.

By E. B. Blakeslee, *Entomological Assistant, Deciduous Fruit Insect Investigations.*

CONTENTS.

INTRODUCTION.

The study of poisonous gases and their use as a possible means of control of the peach-tree borer, *Sanninoidea exitiosa* Say, of which the present paper is a brief report, was begun in 1915, under the direction of Dr. A. L. Quaintance, in charge of deciduous fruit insect investigations, of the Bureau of Entomology. In this investigation the attempt has been made to develop a method of control by the use of local applications of volatile toxic compounds in the soil at the base of the trees. On account of the intimate association of the insect and its host, any gas fully efficient as a larvicide must necessarily have more or less effect upon the tree. In this respect, however, the problem presents nothing unusual, as the application of insecticides generally and the fumigation of living plants especially is restricted to a greater or less extent by the same limitation. In the case of the peach-tree borer the insect and its host are by no means susceptible to fumigation in the same degree. Also, for various reasons, a much wider margin of safety to the tree is afforded by some gases than by others.

It has been necessary, in regard to fumigation, to take into consideration the manner in which it is affected by soil and atmospheric temperatures, soil type, soil moisture, rainfall, seasonal development of the insect and its host, and their relation to the chemical properties of the materials tested, such as the volatility and solubility of the gas, etc. In 1916 daily determinations of soil moisture and records of soil and atmospheric temperatures and rainfall were obtained in connection with each experiment, but on account of the

infinite variation of such factors under field conditions it has been found impossible to correlate these data with the results of the experiments except in a very general way. For the most part, therefore, conclusions have been based on the results of fairly extensive field tests with only a general analysis of the conditions involved.

A number of substances have been tested and many data accumulated which it is impossible to include in the present paper. In so far as promise of providing a safe and effective control measure for the insect is concerned, all of the gases tested have given negative results except one, p-dichlorobenzene. The results obtained from the use of this material are so promising that it has seemed best to report upon the present experimental status of the work for the information of others interested in the problem. Also it is hoped that as far as possible useless duplication of work with some of the other less promising gases may be prevented.

EXPERIMENTAL PROCEDURE.

As already stated, the essential idea of the experiments involves application of volatile toxic compounds to the soil at the base of the trees. In one experiment small tents were used to confine the gas, but this method, on account of the mechanical difficulties involved, was never used to any great extent. The soil under all ordinary conditions proved a fairly satisfactory container for the gas. Whether the material was applied in water solution or in its original form depended upon its chemical properties. Whenever possible both methods of application were adopted. When applied either in solution or suspended in water, a trench was dug about the collar of the tree as for "worming" and the required dose, in from 1 to 2 gallons of water, puddled about the trunk, after which the soil was replaced and compacted. When applied in its original state the material, if a liquid, was poured into the soil about the collar, and if a solid, was buried in the surface soil about the trunk.

Two methods of ascertaining results were followed. In the first the treated trees were examined within a short time after application, usually within a few days, the results being judged by the mortality of the larvæ. The interval from application to examination was usually varied sufficiently to determine the toxicity of the fumigation. In the second method the treatments were made either in late fall or early spring and examination made several weeks or several months later, before the infestation of the next season. By this time dead larvæ usually had largely decomposed, and it was necessary to judge the effectiveness of the fumigation by a comparison of the number of active larvæ escaping on the treated trees with the num-

ber active on untreated trees in adjoining rows. In all cases the effect of the fumigation on the tissues of the tree was carefully noted, the margin of safety being considered as fully as the larvicidal action of the gas. Injury to the trees has been classified under the following terms: Trace, slight, moderate, severe, and maximum. Maximum injury applies to cases where the tree has been girdled completely by the fumigation, and no doubt remains of its immediate death. Severe injury indicates that the tree has been girdled partially, sufficient to destroy permanently its productive value, but not to cause its immediate death. The other terms, moderate, slight, and trace, represent a gradually diminishing degree of injury, the last term indicating that the effect of the gas was only sufficient for identification. The first two terms, trace and slight, represent injury which is of little or no importance as far as the effect upon the tree is concerned.

EXPERIMENTAL RESULTS.

MISCELLANEOUS GASES.

The principal materials that have been tested are carbon disulphid, carbon tetrachlorid, hydrocyanic-acid gas, naphthalene, and para-dichlorobenzene. In the discussion of the relative merits of these materials the results are given in detail only for the last, p-dichlorobenzene.

Carbon Disulphid.

In 1902 Woodworth[1] recommended the use of carbon disulphid against the western species of peach borer. Under the proper condition of soil moisture and temperature it is a most efficient larvicide. In practice, however, it was found impossible to standardize its use to an extent which would make it both safe and effective. The main difficulty with this material arises from its great volatility at ordinary temperatures, which makes it very sensitive to variations in soil porosity. In very dry or porous soils, large doses of several ounces may be applied with no effect upon the larvæ. On the other hand, in very moist, tight soils, large vigorous 12-year old trees have been entirely girdled by an application of as small a dose as one-fourth of an ounce. Its application in water emulsion was found to standardize soil conditions greatly, and successful treatments by this method with greatly-reduced doses have been made on hundreds of trees without injury. A very slight misjudgment in dosage for a given set of conditions, however, gave results of an opposite character, and after two and one-half years' experience with this gas its use has been entirely abandoned.

[1] Woodworth, C. W. The California peach-tree borer. Cal. Agr. Exp. Sta. Bul. 143. 1902.

Carbon Tetrachlorid.

Carbon tetrachlorid does not differ essentially from carbon disulphid, in so far as its effect upon the tree or its larvicidal action is concerned. To achieve the same result it seemed to require about double the dosage of the disulphid. Its chief merit as a fumigant seems to lie in the fact that the vapor is not inflammable.

Naphthalene.

Naphthalene was tested quite fully in 1916 and 1917. For the greater part of the year it vaporized just fast enough to give the soil about the base of the tree a pronounced odor, but apparently produced no effect upon the insect or the tree. With a soil temperature of 70° F. and over, attained in July and August, there is a very decided larvicidal action, but not sufficient to make this material of value.

Hydrocyanic-acid Gas.

Hydrocyanic-acid gas, while a very effective larvicide, proved too dangerous. The great solubility of this gas effectually prevents the standardization of its use. Variation in moisture content and in the type of soil so greatly affect the absorption of this gas by the latter that it has been found impossible to establish any standard dosage that is both effective and safe for any number of conditions. Moist soils required much larger doses than dry soils or soils of low water-holding content. This point has been fully covered by Ong[1] in a recent publication. The great solubility of the gas, furthermore, leads to its rapid absorption by the portions of the tree with which it comes in contact, which probably explains in part the considerable injury resulting from its use.

PARA-DICHLOROBENZENE.

Insecticidal, Physical, and Chemical Properties.

Of the various volatile compounds tested, the merits of some of which have been briefly discussed, para-dichlorobenzene has been by far the most promising. While well known chemically, its value as an insecticide is of comparatively recent discovery.

Of the various volatile compounds tested, the merits of some of which have been briefly discussed, para-dichlorobenzene has been by far the most promising. While well known chemically, its value as an insecticide is of comparatively recent discovery. Duckett,[2] in 1915, published a report on the insecticidal value of its vapor as a fumigant against various insects. Later in the same year Cook,

[1] Ong, E. R. de. Hydrocyanic-acid gas as a soil fumigant. *In* Jour. Agr. Research, v. 11, no. 9, p. 421–436. 1917.

[2] Duckett, A. B. Para-dichlorobenzene as an insect fumigant. U. S. Dept. Agr. Bul. 167. 1915.

METHOD OF APPLYING PARA-DICHLOROBENZENE FOR CONTROL OF THE PEACH-TREE BORER.

Above: Tree with soil crust broken about the collar and one ounce of para-dichlorobenzene applied.
Below: Same tree with soil placed over the material and compacted.

Hutchison, and Scales[1] reported rather indifferent results from its use against fly larvæ in horse manure. Moore[2] used it in 1916 in the fumigation of animals to destroy their external parasites and found it less effective for that purpose than nitrobenzene. Its chemical formulæ and physical properties are discussed fully in Duckett's report. It is a crystalline solid at ordinary temperatures, insoluble in water, melting at 53° C., and boiling at 172° C. Like naphthalene it vaporizes much below its boiling point, although only very slowly at ordinary temperatures. Its vapor pressure and rate of volatilization are discussed on page 21. Apparently, however, when vaporization takes place in a closed container of a capacity appropriate to the dose, or under conditions approximate to that, the evolution of gas even at ordinary temperatures is sufficiently rapid to produce eventually an atmosphere of toxic saturation.

Method of Application.

The method of application for the use of p-dichlorobenzene against the peach borer is illustrated in Plate I. The mechanical condition of the material, on account of its relation to the rate of evaporation, is of considerable importance. The action of the gas is quite local and an even distribution about the tree is highly desirable. It was found that p-dichlorobenzene was most convenient and satisfactory for use when pulverized to about the fineness of coarse salt or granulated sugar. The form in which it usually appears on the market may be reduced to this condition by crushing and sifting through a 12-mesh screen. In this condition it does not lump badly, can be evenly distributed, and vaporizes at about the proper rate.

In making application the soil crust is first broken to a depth of 1 or 2 inches with a hoe, or some other suitable tool. The vapor of p-dichlorobenzene is about five times heavier than air and it is not desirable to apply it deeper than is necessary to avoid washing and surface loss of gas. The soil is not scraped away from the collar of the tree unless there is a decided mound. The material is placed as nearly as possible at the level of the uppermost galleries. The soil, moreover, should not be disturbed except to break up the surface crust. The gas will permeate very tight soils readily, and any unnecessary digging up of the soil about the collar only makes more air space to be saturated, and increases the chance of ineffective fumigation. After the preparation of the soil surface the p-dichlorobenzene is sprinkled as evenly as possible about the collar of the tree in a band 1 or 2 inches wide. In practice the material may be con-

[1] Cook, F. C., Hutchison, R. H., and Scales, F. M. Further experiments in the destruction of fly larvæ in horse manure. U. S. Dept. Agr. Bul. 245. 1915.

[2] Moore, Wm. Fumigation of animals to destroy their external parasites. *In* Jour. Econ. Ent., v. 9, no. 1, p. 71–78. 1916.

veniently carried in an open pail and the dose measured in a graduate holding just the desired amount. A little preliminary practice with the graduate and scales enables one to gauge the dosage very correctly. It is probably best to keep the material from actual contact with the bark by perhaps half an inch, although the practical importance of this precaution is not known. Finally, the material is covered to a depth of 2 inches with two or three shovelfuls of soil, and this slight mound compacted by a few sharp blows with the back of the shovel. The soil is the container for the gas, and the success of the fumigation depends upon the vapor being given off faster than it is lost. At best there is considerable surface loss of gas, and the final compacting of the soil is of considerable importance. No lumps or stones are left against the trunk above the surface to furnish a harbor behind which newly-hatched larvæ may begin feeding out of reach of the vapor. No effect, of course, can be produced upon larvæ feeding in galleries above ground.

Larvicidal Action.

To determine the actual larvicidal value of the vapor of p-dichlorobenzene, a series of applications were made to trees in the field at Springfield, W. Va., in 1916. The approximate limits of effective dosage had been fairly well established by preliminary experiments. Each dose was applied to 20 trees and these examined in lots of 5 at approximately weekly intervals.

Table I gives the summarized results of several such tests. It is impossible to include all of the experiments made in this connection, but the data given bring out the essential facts in regard to dosage efficiency. The soil on which these experiments were made is classified as Frankstown silt loam.[1]

[1] Determination of soil type furnished by the Soil Survey of the Bureau of Soils, United States Department of Agriculture.

TABLE I.—*Larvicidal action of stated doses of p-dichlorobenzene after specified periods of fumigation. Springfield, W. Va., 1916.*

Dose per tree.	Date of application.	Number of trees.	Date of examination.	Number of days from application to examination.	Number and condition of larvæ of specified maturity.														
					Dead.					Stupefied.					Active.				
					One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.	One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.	One-fourth grown.	One-half grown.	Three-fourths grown.	Full grown.	Total.
One ounce	July 19	5	July 28	9	6	18	6	2	32	1	4	1	.....	6	.....	.....	.....	.....	.....
		5	Aug. 2	14	2	16	8	3	29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Aug. 9	21	2	11	17	10	40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		4	Aug. 21	33	.....	6	5	3	14	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Aug. 17	5	Aug. 24	7	21	1	1	1	24	.....	5	.....	.....	5	1	.....	.....	.....	1
		5	Aug. 31	14	21	7	1	1	30	1	2	1	.....	4	5	2	.....	.....	7
		5	Sept. 11	25	13	3	.....	.....	16	1	2	.....	.....	3	.....	.....	.....	.....	.....
		5	Sept. 25	39	.....	.....	1	1	2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
One-half ounce	July 19	5	July 27	8	1	5	3	1	10	2	3	.....	.....	5	.....	.....	.....	.....	.....
		5	Aug. 2	14	1	3	5	2	11	1	.....	.....	.....	1	.....	.....	.....	.....	.....
		5	Aug. 9	21	1	5	9	2	17	.....	.....	.....	.....	.....	.....	1	.....	.....	1
		5	Aug. 21	33	2	6	3	4	15	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Aug. 17	5	Aug. 24	7	6	1	.....	.....	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Aug. 31	14	10	4	.....	.....	14	2	2	.....	.....	4	.....	.....	.....	.....	.....
		5	Sept. 11	25	1	2	2	.....	5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
		5	Sept. 25	39	1	1	.....	.....	2	2	2	1	.....	5	.....	.....	.....	.....	.....
One-fourth ounce.	Aug. 17	5	Aug. 24	7	16	3	1	.....	20	3	2	.....	.....	5	1	1	.....	.....	2
		5	Aug. 31	14	7	1	.....	.....	8	2	1	.....	.....	3	2	1	.....	.....	3
		5	Sept. 11	25	5	2	.....	.....	7	2	1	.....	.....	3	2	1	1	.....	4
		5	Sept. 25	39	.....	.....	1	.....	1	.....	.....	.....	.....	.....	26	1	2	.....	29
Total	.....	99	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

It was found necessary in this work to differentiate between what were apparently normally active larvæ and those which, although slightly active, were visibly affected by the gas. The larvæ therefore were classified into dead, stupefied, and active. Whether stupefied larvæ eventually recover or die seemed to be largely a question of the duration and toxicity of the fumigation, and the degree to which the larvæ were affected. Stupefied larvæ when placed in the open air sometimes recovered and sometimes died, but the determination of the exact condition under which either took place was impossible. It was determined, however, that larvæ apparently much affected may be revived. On the other hand, when the dosage was sufficient to provide for a continuation of the fumigation much beyond the time at which the examination was made it may be assumed with safety that the stupefied larvæ eventually would have been killed.

In Table I it will be seen that a 1-ounce dose, applied July 19, showed 9 days after application a small number of larvæ stupefied. By the time of the next examination, however, 14 days after application and in the two succeeding examinations, the larvæ were all dead.

Very little can be added to these data by an extended discussion. The principal facts in regard to dosage are brought out in Table I. In the study of the table, however, it should be emphasized that the relative numbers of dead and living larvæ in the last two examinations for each dose are somewhat misleading, due to the early decomposition of many of the dead, especially the smaller ones. The 1-ounce and one-half-ounce doses were more quickly and fully effective in the July applications than in the August applications. The one-fourth-ounce dose applied August 17 was partially effective but its action was not sustained, and by the time of the last examination, 39 days after application, the dose had been dissipated so completely that young larvæ which were hatching at the time were able to enter the trees. The one-half-ounce and the 1-ounce doses both gave very complete immunity from this current infestation of newly hatched larvæ. The importance of this point will be emphasized later in connection with the time of application and the final control obtained from the use of this gas.

It was observed that the larvæ of the fungus-gnat, *Mycetobia* sp., which feed in the gum, apparently succumb to the action of the gas in about the same proportion as do the larvæ of *exitiosa*.

From the results of the experiments with p-dichlorobenzene given in Table I it will be seen that at the soil temperatures prevailing in late July and August a dose of 1 ounce per tree has a very effective larvicidal action. The vapor apparently acts rather slowly, how-

ever, and no definite statement can be made as to the exact time required for the gas to kill all the larvæ. This, of course, depends upon the concentration of the soil vapor and the condition of the insect. These points are discussed more fully in a later paragraph. Occasionally larvæ subjected to the fumigation apparently live for weeks in a comatose condition, their bodies shrinking to one-half or one-third normal size before death. There is no means of knowing whether this is due to an unequal distribution of the gas or to the greater vitality of the individual so affected. As a rule, after the application of an effective dose in late summer and early fall most of the larvæ are killed within a period of about two weeks.

Use as a Control Measure.

TIME OF APPLICATION.

The extent to which an application of p-dichlorobenzene may act as a control measure for the peach-tree borer depends greatly on the season of the year in which it is made. In the central latitudes, where most of the experimental work was done, the hatching period of the insect extends more or less over at least three months—July, August, and September. In exceptional seasons, and perhaps to some extent every season, it may be extended from one to two weeks in either direction from these limits.

It has been found that a single application of an effective dose made in the early fall gives a very fair degree of control. Apparently the ideal time would be from two to three weeks before the end of the hatching period. Applied at that time it kills all the larvæ except a few of the more perfectly protected that have already entered the tree, and provides an immunity from the attacks of those which hatch later and appear during the progress of the fumigation. Also the soil temperatures at this time are sufficient to vaporize most of the material before winter, a point discussed in a later paragraph in connection with injury. The seasonal fluctuations in the period of egg deposition prevent the determination of the time of application to any very great degree of exactness. The period for effective application, however, apparently has no arbitrary time limits. Table II gives the summarized results of about 15 experiments carried on in West Virginia, Virginia, and Maryland in 1916, 1917, and 1918.

TABLE II.—*Relative effectiveness of a single fall application of stated doses of p-dichlorobenzene. 1916–1918.*

Observation.	Application per tree.				Check untreated.
	¼ ounce.	½ ounce.	¾ ounce.	1 ounce.	
Total number of trees	10	88	272	298	224
Number of trees not infested	4	61	226	256	22
Number of trees infested	6	27	46	42	202
Total number of larvæ	25	90	98	85	1,669
Maximum number of larvæ on one tree	11	9	6	6	44
Average number of larvæ per tree for trees infested	4.1	3.3	2.1	2	8.2
Average number of larvæ per tree for total number of trees	2.5	1	.36	.28	7.4
Approximate percentage of control	70	88	95	96	0

The time of application varied from the last of August to the last of September, yet in no case was there a very decided departure from the general average of control given in the table. In some cases when application was made about the 25th of August the fumigation was apparently over a little too soon, indicated by a slight infestation of newly hatched larvæ. On the other hand, applications made the last of September, while entirely effective, had the disadvantage of incomplete evaporation. The ideal time apparently was in early September, approximately the 10th.

In 1917 about 80 trees were treated at Springfield with a 1-ounce dose each. One plat received one application on July 7; one plat two applications, the first on July 7 and the second on August 24; and one plat one application on August 25. The plat receiving one application July 7 gave a control of 45 per cent when examined on October 11. The plat receiving two applications gave a control of 96 per cent, and the plat receiving one application on August 25, 90 per cent. Table III gives the results of this treatment.

TABLE III.—*Relative effectiveness of one and two applications per season of a 1-ounce dose of p-dichlorobenzene per tree, Springfield, W. Va., 1917.*

Applications.		Dates of examination.	Number of trees—		Number of active larvæ.		Percentage of control
Number.	Date.		Treated.	Examined.	Total.	Average per tree.	
1	July 7	Oct. 11	29	20	66	3.3	45
2	do Aug. 24	do	38	20	5	.25	96
1	Aug. 25	Oct. 16	13	13	8	.6	90
Check				28	169	6	0

The difference in control between the plat treated twice and that treated once on August 25 is too slight to be of special importance, and certainly not sufficient to warrant the double application in practice. Aside from consideration of economy two applications per

season have the added disadvantage of subjecting the tree to a double fumigation and a proportionately greater chance of injury, although no injury was observed on the trees so treated.

While very good results have been obtained from applications made all the way from the last of August to the last of September, very late application has been less satisfactory. In 1916 the 1-ounce dose was applied to 48 trees at Springfield on November 1. Examination was made the following spring on May 28, about seven months later. Large numbers of dead and decomposing larvæ were found on the trees. An unusual number, however, had escaped. Compared to adjacent untreated trees the indicated mortality was 87 per cent. A slight amount of the material was still in the soil, and from the appearance of the larvæ it was suspected that a considerable part of the fumigation had taken place in the spring. There was also more or less injury about wounds and exposed tissue. The larvæ are probably much more resistant to fumigation during the dormant period than at any other season of the year.

It has been found that with all gases the trees recover more readily from injury which occurs in early spring just at the beginning of the growing season than at any other time of the year, and other things being equal that would be the logical time to apply fumigation. Records of soil temperatures made at Springfield in 1916, however, indicate that the soil warms up rather slowly in the spring. At a depth of 6 inches the temperatures of the period from September 15 to October 15 were not attained in the spring until about May 15 to June 15. It is hardly probable that effective application could be made in the spring much before May 15. By this time a great number of the larvæ have reached a considerable degree of maturity at the expense of much injury to the tree, and while the gas would probably reach a large proportion, the depth and character of the burrows of the larger larvæ provide more or less chance for their escape.

As already stated, early fall, from two to three weeks before the end of the hatching period, proved the most effective time for application. In the latitude of Washington this is about the 10th of September. At this time larvæ that have already entered the trees are mostly small, feeding in the outer layers of bark in more or less exposed locations, while the soil temperature is sufficient to evaporate the material before winter.

For other localities both north and south of the latitude of Washington, the time of application undoubtedly can be established approximately from what is known of the insects' seasonal history in various parts of the country. In Table VI it will be seen that there was a wide variation in the dates applications were made in the same locality in 1916, 1917, and 1918. As a matter of fact, all of the appli-

cations of 1918 were made from two to three weeks later than was originally planned, and, while the results of these experiments were quite satisfactory so far as the larvicidal action was concerned, a considerable amount of the material remained about the trees at the time examinations were made. There is reason to believe that the dates originally adopted are more satisfactory. These dates are as follows:

Michigan, Ohio, Connecticut	September 1
New Jersey, West Virgina, Maryland	September 10
North Carolina and the Ozarks	September 25
Georgia and Texas	October 10

In the study of Table VI it should be remembered that the examinations were made several weeks and in some cases several months after application. Dead larvæ, of course, were largely decomposed after such a lapse of time. Hence no account was taken of anything but living larvæ. Dead skins and partly decomposed bodies were always in evidence but no attempt was made to determine the actual infestation from their numbers. The check plat by which the relative infestation was judged in all cases was made up of consecutive trees in adjoining parallel rows.

DOSAGE.

Table VI sets forth with sufficient clearness the essential features of dosage efficiency. It will be seen that the doses applied as a single fall treatment gave results which agree very closely with their previously determined larvicidal value given in Table I. The trees treated in these experiments varied in age from 6 to 15 years and in size at the butts from one to several inches in diameter. It might be argued that the collar girth of the trees would be a better index to the dosage required than their age. There are certain facts, however, which make this undesirable. First, as will be shown later, injury is more dependent upon the age of the tree and the development of protective tissue than upon its size. Second, there has been a wide latitude in the size of trees treated successfully by a given dose. Under field conditions there is at all times a heavy surface and lateral loss of gas. It seems probable for that reason that there is a certain area of gas diffusion necessary before the vapor in the center of this area attains toxic concentration. There are, of course, limits in both directions in the application of this statement, very large trees undoubtedly requiring larger doses than small ones. In practice, however, the latitude in collar girth of trees which a given dose will treat successfully has been enough to cover the usual variation in trees between the ages of 6 and 15 years.

It will be seen in Table VI that the one-fourth-ounce dose gave only partial control. Although only one experiment included the application of this amount, the results agreed fairly well with its

previously determined larvicidal value. The one-half-ounce dose in many instances gave as perfect control as the next two larger doses, and in some cases better. On the whole, however, the results from the application of this dose are not quite so uniform and the general average is slightly less. As will be seen from the table, there is not a great difference in the control obtained from either the one-half-ounce, the three-fourths-ounce, or the 1-ounce doses. Apparently there is considerable latitude in the dosage required, within these limits, but it does not seem likely that much less than one-half-ounce doses would give consistent control. On the other hand, there does not seem to be much point in using doses larger than 1 ounce.

Other experiments were carried on in which very much larger doses than those shown in Table VI were used, but in none of these was there an advantage in the control obtained sufficient to offset the probability of injury from the greatly prolonged fumigation. Table IV gives the results of one such experiment, made at Springfield in 1916.

TABLE IV.—*Effect of stated doses of para-dichlorobenzene on 8-year-old peach trees, Springfield, W. Va., 1916.*

Number of trees.	Dose per tree.	Date of—		Interval in days from application to examination.	Number of active larvæ.		Injury.
		Application.	Examination.		Total.	Per tree.	
5	½ ounce	June 24	Oct. 14	112	29	5.8	None.
5	do	do	Oct. 27	125	12	2.4	None.
5	do	do	Oct. 28	126	3	.6	None.
5	do	Aug. 22	do	67			None.
5	1 ounce	June 24	Oct. 14	112	9	1.8	None.
5	do	do	Oct. 18	116	25	5.0	None.
5	do	do	Oct. 27	125	15	3.0	None.
5	do	do	do	125	6	1.2	None.
5	do	Aug. 22	Oct. 28	67			None.
5	2 ounces	June 24	Oct. 14	112			None (1 tree moderate).
5	do	do	Oct. 18	116	3	.6	None.
5	do	do	Oct. 28	126	4	.8	None.
5	do	do	Oct. 27	125			None.
5	do	Aug. 22	Oct. 28	67			None.
5	3 ounces	June 24	Oct. 14	112			None.
5	do	do	Oct. 27	125			None.
5	do	do	Oct. 28	126			None.
5	do	do	Oct. 27	125			None.
5	do	Aug. 22	Oct. 28	67			None.
5	4 ounces	June 24	Oct. 14	112			None (1 tree severe).
5	do	do	Oct. 27	125			None.
5	do	do	Oct. 28	126			None.
5	do	do	do	126			None.
5	do	Aug. 22	do	67			None.
2	6 ounces	do	do	67			None (1 tree traces).
2	8 ounces	do	do	67			Traces.
2	10 ounces	do	do	67			None (1 tree traces).

Total number of trees treated, 126.

A total of 126 eight-year-old trees were treated with various doses, ranging from one-half ounce to 10 ounces per tree. Part of the applications were made June 24 and part August 22. The examination was made in October. Of the entire 126 trees, 56 which received

3 ounces each and over were entirely free from larvæ; 20 trees receiving 2 ounces each on June 24 contained 7 larvæ, an average infestation of 0.35 per tree; 5 trees receiving 2 ounces each August 22 contained none; 20 trees receiving 1 ounce each on June 24 contained 55 larvæ, an average infestation of 2.7 per tree; 5 trees receiving 1 ounce each on August 22 contained none; 15 trees receiving one-half ounce each on June 24 contained 54 larvæ, or an average of 3.6 per tree; and 5 trees receiving the same dose on August 22 contained none. It is especially significant that the single application of a moderate dose the last of August gave as good control, in the end, as a June application of a much larger dose.

INFLUENCE OF SOIL TYPE.

So far as the present experiments go the influence of soil type on the effectiveness of the application of p-dichlorobenzene has imposed no limitations on its use. While the fumigation probably may be expected to prove somewhat less effective in some cases where extreme variation in soil types exists, it has been used so far with almost uniform results on a variety of soils. In this respect it possesses a distinct advantage over gases like carbon disulphid and carbon tetrachlorid, which volatilize so rapidly at ordinary temperature that the fumigation is over in a few days. The relative diffusion of gases at various times in a given soil type depends mainly on the variation of moisture content. A highly volatile gas for that reason possesses a distinct disadvantage, since it is governed entirely by the particular condition of the soil, with respect to moisture, which exists within a period of a few days. This condition may be one of extreme dryness or extreme wetness, or, in case of a heavy rain, both conditions may be present. It is apparent, therefore, that a material of low volatility at ordinary soil temperature, which gives a comparatively mild fumigation, and requires a long period for its action, not only takes advantage of the equalization of soil moisture conditions that usually occurs over a period of several weeks, but at the same time is less seriously affected by sudden violent fluctuations that may occur at any time.

Table VI gives the results obtained on several types of soil varying in character from sandy loam to comparatively heavy clay loam. At Pinto, Md., where the soil type is a variation of the Frankstown series, known as stony silt loam, locally called chert land, the greatest difficulty is encountered in its use. When cultivation of this soil is followed for some time, it appears often almost entirely free of fine material on the surface. Below the immediate surface, however, it is usually well filled with fine soil. The chief difficulty in making application to this type of soil was due to the lack of fine material. As will be seen in Table VI the results were quite

satisfactory on this type of soil, and the mechanical difficulty involved in its application would probably be no greater than in "worming."

For the types of soil upon which experiments have been made no consistent variation in control has so far been observed. The comparative mildness of the fumigation and the long period over which it acts apparently tend to neutralize the influence of soil type.

Injury to Trees.

The margin of safety in the use of p-dichlorobenzene against the peach-tree borer apparently depends entirely upon the relative extent to which the insect and the tissues of its host are exposed to the action of the gas. In the main this relation varies in proportion to the age of the tree and the development of its protective tissues. It has been found impossible to fumigate young trees with safety. On the other hand trees beyond a certain age have shown so far no ill effects from a fumigation of several times the duration necessary to kill the insect.

In the course of three years' work many hundreds of observations have been made on the collars of trees treated with a great variety of doses on a number of different soils. In some cases blocks of trees have been treated for two successive seasons and in one case for three years. In part, the observations have been made in connection with "worming" data, and in part they are the results of separate dosage experiments.

NURSERY TREES.

In 1916, 57 nursery trees were treated in a nursery at Hagerstown, Md. The trees were Belle of Georgia buds of the previous fall. The soil was a stiff clay loam. The dosage was distributed over the 57 trees as follows: 10 received one-fourth ounce each; 10 one-half ounce; 10 three-fourths of an ounce; 10, 1 ounce; 5, 2 ounces; 5, 3 ounces; 2, 4 ounces; 2, 5 ounces; and 3 individual trees received 6, 8, and 10 ounces, respectively. The application was made on September 6. On October 21 the trees were dug and examined. In this interval of 45 days all of the trees had been injured severely by the gas. No distinction could be made between the various doses in the extent of the injury, which was as severe on trees receiving one-fourth ounce as on those receiving more. The injury was localized on the collar and larger roots lying within 6 to 8 inches of the material. The greatest amount of tissue killed was in the vicinity of wounds, but even on uninjured stems where the epidermis was not ruptured the surface was peppered with tiny lesions extending into the cambium.

TWO-YEAR ORCHARD TREES.

The effect upon two-year orchard trees proved less serious, although much too great to make their fumigation practicable. On August 18, 1916, 20 Belle of Georgia trees were treated in an orchard at Vienna, Va. These trees were in their second season from planting and were consequently two years older than the nursery trees. The soil was exceptionally stiff clay loam. With one or two exceptions these trees were vigorous and normal. Table V gives the date of application, dosage, and the results of later observations on the effects of the fumigation.

TABLE V.—*Effect of stated doses of para-dichlorobenzene on 2-year-old Belle of Georgia peach trees, Vienna, Va., 1916–17.*

Tree Nos.	Condition of trees before treatment.	Dose.	Date of application.	Condition of trees on specified dates of examination.	
				Mar. 14, 1917.	July 24, 1917.
			1916.		
1	Normal	¼ ounce	Aug. 18	Moderate injury, not serious	Fully recovered, normal growth.
2	do	do	do	Slight injury, not serious	Do.
1	do	½ ounce	do	do	Do.
2	Weak	do	do	Dead	
1	do	¾ ounce	do	Slight injury, not serious	Do.
2	Normal	do	do	Severe injury, girdled	Dead.
1	do	1 ounce	do	Severe injury, three-quarters girdled.	Partly recovered, normal growth.
2	Weak	do	do	Slight injury, not serious	Fully recovered, normal growth.
1	Normal	2 ounces	do	do	Do.
2	do	do	do	Severe injury, girdled	Dead.
1	do	3 ounces	do	Slight injury, not serious	Fully recovered, normal growth.
2	do	do	do	Severe injury, three-quarters girdled.	Partly recovered, normal growth.
1	do	4 ounces	do	Severe injury, girdled	Dead.
2	do	do	do	Traces injury, not serious	Fully recovered, normal growth.
1	do	5 ounces	do	Severe injury, serious	Partly recovered, normal growth.
2	do	do	do	Traces injury, not serious	Fully recovered, normal growth.
1	do	6 ounces	do	Slight injury, not serious	Subnormal, stunted.
2	do	do	do	Traces injury, not serious	Fully recovered, normal growth.
1	do	8 ounces	do	Moderate injury, not serious	Do.
1	do	10 ounces	do	Severe injury	Subnormal, stunted.

It will be noted by reference to Table V that for all doses up to and including 5 ounces the injury to one tree is recorded as "slight" or less, while the other was injured more severely. Table V also shows that on July 24, 1917, when they were again examined, all injured slightly had recovered and made a normal growth. For each dose, therefore, up to and including 5 ounces, one tree entirely recovered and made a normal growth the season following fumigation. Apparently for the period over which the experiment was allowed to run, the smaller doses were sufficient to furnish a vapor of maximum toxicity. Had the experiment been allowed to run longer, it is probable that a greater graduation in the toxicity of the various doses would have been observed, as the larger doses had by no means completely volatilized at the time the examination was made. As in

the case of the nursery trees, the greatest injury occurred about wounds. There was noticeably less injury where the protective tissue was not ruptured than on the uninjured stems, although in many cases the gas had killed large patches and partly girdled uninjured collars.

FOUR-YEAR ORCHARD TREES.

Four-year orchard trees showed a still greater resistance to the effects of the gas. On September 9, 1916, 28 four-year Champion trees were treated in an orchard at Conway, Md., with doses as follows: Nine received one-half ounce each, 9 three-fourths of an ounce, and 10 one ounce. Five trees of each plat were examined on November 28, 1916, and the remainder on April 2, 1917. Of the entire 28 trees, 17 showed no injury at all. Of the 9 trees which had received the one-half ounce dose 7 showed no injury, while 2 were injured, 1 moderately and 1 severely. On the three-fourths-ounce plat 5 of the 9 trees showed no injury, 4 were injured, 2 severely, 1 moderately, and 1 only a trace. On the 1-ounce plat 5 of the 10 trees were uninjured; of the remaining 5, 3 showed only a trace of injury, 1 a slight injury, and 1 was entirely girdled. Of the entire lot of 28 trees only 1 was killed outright. While one or two others were partly girdled, the one last mentioned was the only tree upon which the effects of the fumigation were ever visible above ground. As usual the injury occurred more or less irrespective of dosage, its severity varying with the condition of the tree with respect to insect wounds, etc. While it was apparent that four-year trees could not be fumigated without more or less injury on lacerated stems, there was a decided diminution in its severity on trees of this age compared to those younger.

The extent to which the epidermal and cork layers of the bark are responsible for the protection of the tree was illustrated by an experiment at Springfield in 1916. A block of eight 10-year-old trees was treated with 1, 2, 3, and 4 ounce doses on July 20, two trees receiving each dose. On August 26 they were examined and no trace of injury found. However, in making the examination the trees of the 2, 3, and 4 ounce plats were considerably scarified, the outer layer of the bark being largely pared and scraped away. These trees were retreated with the same dose August 26, and examined again on October 28. On the 1-ounce plat where the collars were not scarified no injury had developed. On the other plats all the trees were injured severely, and in two cases completely girdled. On the other hand, trees of the same age in adjoining rows withstood during the same period continuous fumigation for 125 days without injury.

TREES SIX YEARS AND OVER.

A single early fall application of a moderate dose of p-dichlorobenzene has caused no injury on trees six years and over. Doses have been applied to trees of this age varying from 1 ounce to several ounces per tree. Where moderate doses of three-fourths of an ounce or 1 ounce per tree have been applied once in early fall no injury of any importance has ever been observed. Hundred of trees have been fumigated in this way, and in some cases blocks of trees have received the same doses for two and three years. While there can be no doubt that trees of any age could be killed if the fumigation was prolonged sufficiently, there is every indication that the time required would be many times that necessary to kill the borer. Occasionally in the vicinity of wounds a slight amount of tissue is killed even in fumigation with ordinary doses, but on the older trees this has been so slight and superficial in character that it may be disregarded.

Table IV gives the results of prolonged fumigation on eight-year-old trees at Springfield in 1916. As will be seen from the data there presented very little injury of importance was found on trees treated with doses giving a continuous fumigation from June 24 to the last of October. Of the entire 126 trees treated with doses ranging from one-half ounce to 4 ounces each, only two developed serious injury and in both cases the trees had been seriously injured by both borers and crown gall. Apparently the gas has considerable effect upon the spongy galls which accompany this disease. Doses of 2 ounces and over gave off a very pronounced odor when the earth was opened, and the fumigation had probably been maintained at a toxic concentration throughout most of the period from June to October. While from the standpoint of control a fumigation of so great duration is not necessary or desirable, it is interesting that all these larger doses gave almost complete immunity from the insect throughout the season.

The greatest amount of injury ever observed on older trees resulted from an application made at Springfield on November 1, 1916. (See Table VI.)

TABLE VI.—*General summary of results obtained by one fall application of para-dichlorobenzene per season, 1916–1918.*

Date of application.	Locality.	Number of seasons applied successively.	Soil type.	Treatment and results.																							Remarks.
				¼ ounce.				½ ounce.				¾ ounce.				1 ounce.				1½ ounces.				Check untreated.			
				Number.				Number.				Number.				Number.				Number.				Number.			
				Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	Per cent control.	Trees.	Active larvæ. Total.	Active larvæ. Per tree.	
1916.																											
Aug. 26	Springfield, W. Va.	1	Silt loam	10	25	2.5	69.9	10	16	1.6	80.8	10	3	0.3	96.4	11	2	0.18	97.8					10	83	8.3	9 to 10 year old trees.[1]
Sept. 9	Conway, Md	1	Sandy loam					9	1	.11	98	9	0	0	100	10	0	0	100					10	55	5.5	4-year-old trees.[2]
Nov. 1	Springfield, W. Va.	1	Silt loam													15	16	1.06	87.2					10	83	8.3	9 to 10 year old trees.[3]
1917.																											
Aug. 24	do	2	do									14	10	.72	86.9	25	20	.8	85.5					18	99	5.5	10 to 11 year old trees.[1]
Aug. 28	do	1	do					15	28	1.9	85.8	14	19	1.35	89.9	15	9	.6	95.6					10	134	13.4	6-year-old trees.[1]
Sept. 19	do	1	do					12	0	0	100	12	1	.08	99.4	12	1	.08	99.4					10	134	13.4	6-year-old trees.[1]
Sept. 9	Pinto, Md	1	Stony silt loam									25	13	.52	94.2	25	15	.6	93.4					10	91	9.1	10 to 12 year old trees.[1]
Sept. 7	Three Churches, W. Va.	1	Fine sandy loam									20	0	0	100	20	4	.2	97.4					10	77	7.7	6-year-old trees.[1]
Sept. 11	Hancock, Md	1	do									25	8	.32	96.4	25	6	.24	97.3					20	176	8.8	6 to 8 year old trees.[1]
1918.																											
Sept. 14	Winchester, Va	1	Clay loam					21	43	2.0	78.9	23	24	1.0	89.5	23	7	.3	96.8					21	199	9.5	6-year-old trees.[1]
Sept. 24	Springfield, W. Va.	3	Silt loam									25	3	.12	94.6	20	1	.05	97.7					20	44	2.2	11 to 12 year old trees.[1]
Sept. 27	do	2	do					21	2	.09	98.2	21	1	.05	99	23	0	0	100					20	98	4.9	7-year-old trees.[1]
Sept. 25	Pinto, Md	2	Stony silt loam									25	11	.44	96	25	3	.12	98.9					15	167	11.1	11 to 12 year old trees.[1]
Sept. 26	Three Churches, W. Va.	2	Fine sandy loam									25	2	.08	98.6	25	2	.08	98.6					20	112	5.6	7-year-old trees.[1]
Sept. 30	Hancock, Md	2	do									24	3	.12	97.9	24	0	0	100					20	117	5.8	7-year-old trees.[1]
Sept. 11	Vermilion, Ohio	1	Light clay loam					20	7	.35	96.1	23	25	1.08	88	25	17	.68	92.5					25	225	9	8-year-old trees.[1]
Sept. 15	Sandusky, Ohio	1	Clay loam					25	3	.12	97.5	25	4	.16	96.7	25	6	.24	95					25	121	4.8	7-year-old trees.[1]
Sept. 30	Wakefield, Ohio	1	Light clay loam					25	11	.44	93.7	25	23	.92	86.9	25	36	1.4	80					25	175	7	9-year-old trees.[1]
Oct. 12	Springdale, Ark	1	Gravelly loam													25	6	.24	94.3					25	105	4.2	15-year-old trees.[1]
Oct. 22	Fort Valley, Ga	1	Fine sandy loam					18	2	.11	97.5	19	6	.31	92.8	21	4	.19	95.6	20	1	0.05	98.8	16	69	4.3	15-year-old trees.[1]
Do	do	1	do					18	2	.11	96.2	17	2	.12	95.9	20	5	.25	91.4					18	52	2.9	6-year-old trees.[1]
	Total			10	25	2.5	69.9	194	115	.59	91.7	381	158	.41	94.1	439	160	.36	94.7	20	1	.05	98.8	358	2,416	6.77	

[1] No injury. [2] Moderate injury. [3] Slight injury.

The trees treated were about 10 years of age and had suffered heavily from borer attacks. They received 1 ounce each. On May 28, 1917, 15 were examined. Nine showed no injury at all, 5 showed traces, and 2 what was classified as slight injury. So far as the final effect on the trees was concerned none of this injury was of importance. It was more than hitherto had been observed for this dose, however, and while the reason is not entirely apparent it is felt that it is best to make the application sufficiently early in the fall to allow for complete evaporation before winter. This fact, coupled with its less effective action, should be sufficient reason for avoiding late application. When the application is made in the central latitude as late as September 15, it probably would be wise to uncover the trees after five or six weeks, and either allow them to stand open for a time or refill with fresh earth. In fact, at the present stage of our knowledge of the problem the writer is inclined to feel that this might be a wise precaution to follow in every case.

The varieties treated have included many of the leading commercial sorts as well as a large number of unknown seedlings. So far there has been nothing to indicate that one variety of peach is more susceptible to the effects of the gas than another.

A summary of the results obtained by one fall application of paradichlorobenzene is given in Table VI.

RELATION OF INJURY TO SOIL TYPE.

No special relation between injury and type of soil has been discovered in the use of p-dichlorobenzene. Very porous soils probably give a somewhat less concentrated vapor than very retentive soils, but in practice the effect of soil type has not seemed important, although the soils on which experiments were carried on have varied from light sandy loams to heavy clay loams.

INJURY TO APPLE.

In August, 1916, an application of p-dichlorobenzene was made to twelve 3-year-old apple trees at Springfield, W. Va. These trees were treated with doses varying from 1 ounce to one-fourth of an ounce each. All were quite well infested with *S. candida*. The application was made on August 23 and the examination on September 1–2. Practically all the smaller larvæ of the borer had been killed. The more mature specimens working in deeper burrows were still living, although several were affected noticeably by the gas. The trees were severely injured, however. Apparently, the action of the gas on the insect and the tree was almost simultaneous. Several of these trees were so severely injured that they died the following season. On another occasion an 8-year-old apple tree not infested with borers or injured in any way was treated with an ounce of p-dichlorobenzene.

When examined, about one month later, it was found to be two-thirds girdled by the fumigation. While these observations are very limited they indicate a wide difference in susceptibility of apple and peach. This difference apparently is due mostly to the difference in the thickness of the bark and its layers of protective tissue, which exists between the two.

Discussion.

The experience so far obtained indicates that there are pronounced possibilities in the application of poison gases to the control of the peach-tree borer. At present p-dichlorobenzene remains the only material of decided value. Despite the fact that for three seasons it has given uniformly good results, however, it is not the purpose of this paper to encourage its use except in an experimental way. The control obtained has been by no means 100 per cent efficient, and it is doubtful if such a degree of control could be secured safely by any artificial means. Certainly it is not obtained in practice by the ordinary "worming." Unfortunately the use of this gas is restricted to trees of somewhat advanced age, but this limitation might apply as well to the application of other fumigants for the control of this insect.

The question of the volatility of p-dichlorobenzene was submitted to the Bureau of Chemistry.[1] It was found that the vapor pressure, while very low at ordinary temperature, is, roughly, about ten times as great at 100° F. as at 50° F. In the soil, however, the relation of vapor pressure and temperature to the rate of volatilization is greatly modified by such factors as barometric pressure, humidity, circulation of air, surface exposure, etc. Although there is undoubtedly a considerable variation in the rate of volatilization within the seasonal range of soil temperatures, it has not seriously interfered with the effectiveness of the gas in the field tests so far made. Soil temperature records taken throughout the season of 1916 at Springfield, W. Va., showed a variation at a depth of 6 inches from about 50° to 55° F. in April and October to 75° and 80° F. in July and August.

The vapor of p-dichlorobenzene has a very decided repellent effect upon the ovipositing moths. On several occasions females were followed through treated blocks of trees and observed to visit tree after tree, hovering about the base for a short time or alighting for an instant without depositing a single egg.

The effective range of the gas is rather local, being confined to the area reached in practice by "worming." On the bole of the tree at a depth of from 8 to 12 inches and on lateral roots at less than that depth, but more than 6 to 8 inches from the trunk, larvæ usually are not affected.

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[1] Correspondence and notes of the Bureau of Entomology.

The writer is indebted to a number of observers for cooperation in experiments made in various parts of the country during the season of 1918. In Ohio the treatments and examinations at Sandusky and Vermilion were made by Mr. G. A. Runner, in charge of the laboratory of the Bureau of Entomology at Sandusky, in cooperation with Mr. H. J. Speaker, of the bureau of horticulture, Ohio Department of Agriculture. The work in southern Ohio at Wakefield was conducted by Mr. Speaker. At Springdale, Ark., the observations were made by Mr. A. J. Ackerman, of the Bureau of Entomology, and Mr. F. L. Pierce, of the Bureau of Plant Industry. At Fort Valley, Ga., the work was carried out by Mr. J. J. Culver, of the Bureau of Entomology, and the writer. The writer is also especially indebted to Mr. B. R. Leach, in charge of the bureau laboratory at Winchester, Va., for many valuable suggestions and for cooperation and assistance in the experiments in Virginia, West Virginia, and Maryland.

SUMMARY.

(1) It has been found impossible to standardize the use of carbon disulphid and carbon tetrachlorid as treatments for the peach borer. The great volatility of these substances at ordinary temperatures renders them too sensitive to varying conditions of soil porosity.

(2) Sodium cyanid on account of its solubility was too susceptible to the effects of variation in soil moisture and soil type, and proved to be injurious to trees.

(3) Naphthalene on account of its low volatility within the seasonal range of soil temperatures was only a partially effective larvicide for a very short period in midsummer.

(4) P-dichlorobenzene has proved quite effective over a wide range of varying conditions imposed by field practice, with a considerable margin of safety for trees six years and over.

In making the application the surface crust about the collar of the tree is broken. Excessive amounts of gummy exudations at the surface are removed. The lower levels of soil are disturbed as little as possible, and the required dose is distributed evenly about the trunk in a band 1 to 2 inches in width. (See Plate I, A.) Two or three shovels of earth are then placed over the material, and compacted with the back of the shovel, being mounded slightly to cover surface galleries (Plate I, B).

In the latitude of Washington and northern Virginia about September 10 has been found to be the most satisfactory time of application. Based on the insect's seasonal history, the theoretical time of application in the North generally would be about September 1; in the Ozarks, September 25; and in Georgia and the cotton belt, October 10.

For 6 to 15 year old trees of average size, doses of 1 ounce and of three-fourths of an ounce per tree have been found effective in destroying the borers without injury to the trees. For very large trees of advanced age, a somewhat increased dose may be desirable.

As an added precaution against injury the base of the trees should be uncovered 4 to 6 weeks after application, allowed to remain open for a few days, and recovered. This precaution is especially necessary if the application has been made very late.

The use of p-dichlorobenzene in this way has been found to reduce the infestation on the average from 6.77 to 0.41–0.36 larvæ per tree, approximately a 94 per cent control.

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BULLETIN No. 797

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

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COMMERCIAL DUTCH-BULB CULTURE IN THE UNITED STATES.

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CONTENTS.

BULB PRODUCTION IN THE UNITED STATES.

The production of bulbs in the United States is in its infancy. In normal times the value of the bulbs used in this country is not far from $2,000,000 a year, while those actually produced here are scarcely worth $25,000 in any one year.

This condition exists in spite of the fact that it has been known for generations that narcissus bulbs of perfect quality can be grown over a wide latitude and that tulips, although more exacting in their requirements, can also be produced successfully. Those best informed are just as sanguine about the production of hyacinth bulbs,

but, true to their scientific training, they are inclined to withhold advice and judgment because, so far as is known, no actual demonstration has yet been successfully accomplished on a scale large enough to command respect. The reason for this can be summed up in the phrase "We have thought that all of these stocks could be bought cheaper than we could grow them." Whatever may be the truth regarding this prevalent opinion, whatever may have been the facts in the past, it is very certain that in the future the conditions are going to be different. The dissemination of such information on the subject as is available at this time is therefore pertinent.

In this brief bulletin details have been largely eliminated. The various methods of bulb culture are described, with little attempt to discriminate between them. As American experience is not extended enough to have crystallized into general practices, it is consequently considered advisable to present those methods which have succeeded in this country and abroad. Variations in practice will be inevitable as an industry in bulb production is developed in this country.

Thus far, the commercial production of Dutch bulbs has in this country been confined mainly to the Atlantic and Pacific seaboards, in the former north of Norfolk and in the latter north of San Francisco. The available data are more or less meager in either case, but good bulbs have been produced in both regions.

The western bulb area appears to be rather narrow, being confined to a strip of territory which receives suitable rainfall and is sufficiently affected by seacoast conditions to prevent rapid transition from winter to summer.

The eastern area is much more indefinite as to width, as the heat and moisture conditions are not so sharply defined. In the interior, in the Ohio and Mississippi Valleys, small quantities of tulip and narcissus bulbs have been grown sufficiently long to show the possibility of the successful production of many varieties.

Some of the hardier and more robust of the narcissus varieties thrive well and naturalize even in the Gulf States, but this region is best adapted to the so-called South France stocks. The growing of tulips and Dutch hyacinths probably should not be attempted there.

Contrary to what would be generally supposed, it is not too cold for tulips and narcissi to succeed as far north as Sitka, Alaska. They thrive well along the entire northern border of the United States wherever the moisture conditions are suitable.

From the above it will be seen that these stocks succeed under a great diversity of conditions. Indeed, they seem to be as adaptable as ordinary cultivated crops.

The successes with the three main groups of these bulbs on the northern Pacific coast; the large production of a long list of narcissus

varieties in southern Illinois and Virginia; the culture of Darwin and other tulips in Michigan, northern New York, Ontario, and Virginia, and the admirable hyacinth bulbs often produced in private gardens throughout the region south of New York, under conditions of comparative neglect and a large measure of ignorance of their life history, would seem to prove sufficiently that we have an abundant territory adapted to growing these stocks.

SOIL ADAPTATION.

The culture of bulbs is associated in the public mind with sandy soil, and the preponderance of advice as to their handling specifies sandy soils as preferable to any other. Periodical literature especially is full of reference to the so-called "sand-dune bulb fields" of the Netherlands. Abundant evidence is at hand to show that purchasers of bulbs have good success in flowering them on almost any soil which is available, and though this is a very different matter from producing the bulbs with flowers in them it is nevertheless a proof of the wide adaptability of these stocks.

In the experiments at Bellingham, Wash., thus far, better tulips and better narcissus bulbs have been produced on silty soil than upon the lighter sandy soils. The trials with hyacinths are not decisive; indeed, other factors may account for the results. Proper fertility has not always been maintained, and the heavier soils are less exhausted by long cropping. While this may be true, the fact stands out prominently that the production of tulip, narcissus, and even hyacinth bulbs of good quality can be accomplished on silt-loam soils underlain by clay at a depth of 16 inches. On the other hand, it should be realized that the ability to produce bulbs at a profit will be the controlling factor, and the expense is much less on light than on heavy soils.

When all is said, few plants are more widely adaptable and few crops more easily grown than bulbs. The regions in this country are few and small, indeed, where some varieties of each of the three groups are not successful when grown for ornamentation, and the possibility of the production of bulb crops is promising. The flowering of the bulbs, as we know, is accomplished in a great variety of media, almost anything, from water to ordinary loam soils, answering the purpose provided the atmospheric conditions are suitable.

Mechanics probably has more to do with the suitability of sandy soil than any inherent preference of the bulbs for sand rather than for heavier loam. It is possible that it will be cheaper to add heavy applications of fertilizer than to handle the bulbs in heavy soils. On the other hand, many varieties will coat up better on light

than on heavy soils. The character of the bulbs grown on heavy and on light soils will vary somewhat, of course, as it will with shallow and with deep planting. The indications are that success can be secured in bulb production on a friable loam soil, whether it has a preponderance of sand in its composition or not.

TEMPERATURE, SOIL, AND FERTILITY REQUIREMENTS.

We may gain a valuable lesson as to the requirements and suitability of these bulbs from the long private experiences of those who have flowered them either in pots or in borders in different regions and then tried to carry on their propagation. It is the common experience that these stocks gradually deteriorate in size in the hands of the small grower. This is not always a proof of lack of adaptability, because it is seldom that the stocks are properly handled. They become overgrown with weeds, are left undug too long, or are improperly fertilized.

About 40 miles from the coast in northern California we have a record of an apparent intelligent handling of Darwin tulips over a period of years. Here, with good fertility and proper handling, the bulbs gradually deteriorate in size. Two natural conditions in this locality seem to be accountable. The moisture is likely to fail suddenly before the plants complete their growth, and the temperatures are likely to run suddenly high at the same time, thus shortening the growing period suddenly. Such conditions are evidently not suited to commercial bulb production.

The consensus of experience in the vicinity of the District of Columbia probably would be very similar to that in the interior region of northern California—the bulbs gradually deteriorate in size. In this region, however, the average soil is naturally poor, which, coupled with imperfect growing of small lots, is responsible for much of the failure. There has been recently ample proof that all of the robust varieties of both the nacissus and the tulip can be successfully produced in good quality even here. It is not to be considered, however, that the conditions are by any means ideal. The main adverse condition, aside from natural lack of soil fertility, is the high temperatures, which are normal for May and June and occasionally occur even in April. There is also an uncertainty regarding moisture supply before the end of the growing season.

Suitable temperature, moisture, and soil conditions obtain in both our Atlantic and Pacific coast regions. In the interior of the eastern United States, as far west as Illinois and Michigan at least, conditions are favorable enough for success. The temperature is not as favorable as in the cooler coastal climate, but, in our opinion, where friable well-drained soils occur the conditions are generally as satis-

factory for the production of Dutch bulbs as for the common staple crops usually grown there.

The fertilizer requirement of bulbs is not sufficiently appreciated in this country. These stocks require heavy fertility to produce well and to maintain their size. We have sometimes thought that the better success with narcissus than with other bulbs is due to the fact that this group requires less fertility and is exceedingly impatient of any soil loaded up with organic matter, even when well incorporated. This does not mean that the narcissus requires a lean soil, but that a heavily fertilized soil must not be in contact with the bulb.

The practice of rotation by the bulb grower on the other side of the Atlantic is in this particular instructive. The formula of the rotation may be stated as follows: A heavy application of cow manure in winter, followed by a crop of potatoes dug early and followed by hyacinths one year, tulips the second year, and then narcissi. When the latter are left in for two years they commonly receive a top-dressing of manure the second year. The soil in which the narcissus is planted in this rotation has produced a crop of potatoes, one of hyacinths, and one of tulips. The application of a mulch of manure always works well with the narcissus, because the fertility is secured in the form of leachings. The relative fertility requirements of the bulbs are well exemplified in this rotation.

NUMBER OF BULBS GROWN PER ACRE.

A practical bulb grower will almost invariably shy at a question relating to the number of Dutch bulbs that can be grown on a definite area of ground, especially if the exactitude of the Dutch method be followed. The reason is apparent if we stop to reflect.

Let us analyze an acre's planting on the Dutch plan. Allowing for one 10-foot roadway and the necessary waste on the sides, there is room on an acre for 48 beds with paths 1 foot wide. The length of these beds when the necessary crosswalks are taken out will be not more than 190 feet. If the rows are 6 inches apart 18,240 rows will be planted. Then if 7 bulbs are planted to the row, an acre will be fully occupied by 127,680 bulbs. On the other hand, if 50 bulblets to the row are planted it will take 912,000 to occupy the acre. In round numbers, therefore, the number grown on an acre will range from 125,000 to 900,000, a very wide variation. In practice, the grower may have 20 beds 50 feet long of one variety, and if he sizes his bulbs closely he will plant in those 20 beds, about one-forty-fifth of an acre, 7, 9, 11, 14, 21, 35, and 50 bulbs to the row. It is manifestly very difficult to say how many bulbs can be grown on an acre. The matter is still more complicated by the constant fluctua-

tion in the relation of different sizes, owing to seasonal variation, and, further, by the fact that merchantable bulbs are turned off more closely some seasons than others. In the above case an average, which means but little, would be 8,400 for the area specified. It is on this account that the row and the bed are such prominent units of bulb measurement in the Netherlands. They do not contain the same number of bulbs, but an effort is made to occupy the ground uniformly, and there is consequently about an equivalent quantity of plant material on any given area.

PLANTING.

Long experience and practice have brought the art of planting, as well as other Dutch-bulb operations, to an exact formula. In this country the ground is thoroughly prepared with a plow, disk, and harrow, but in the Netherlands mainly with a spade and rake. It is well to run a float or roller over the field as a final preparation, in order to smooth the surface and compact the soil a little.

FIG. 1.—A field of the Sir Watkin narcissus. Experimental planting at Bellingham, Wash., 1918.

The land is first laid out into plats accurately measured and squared with the aid of a taut line. These plats are then subdivided into beds by means of lines stretched on each side of the 3-foot bed,[1] leaving, with us, a 15-inch path between. (Fig. 1.) At the same time a permanent peg or stake is set at each corner of the bed. These stakes remain throughout the season. The bed is then marked off with a common spade by shoving it into the ground along the line to a depth of 5 or 6 inches and pulling the dirt into the center of the bed by a scraping motion. The soil is then, with a shovel, thrown out of the first bed in the plat to a depth of about 4 inches. Next, the bottom of the bed is smoothed with a garden rake, and a marker is run through, which defines the boundaries, rows, and the center of the planted bed. After this, the bulbs are set out, usually by two men on their knees on either side of the bed. The covering is

[1] While the beds are laid off 3 feet wide and are spoken of as 3-foot beds, bulbs are set on the 3-foot line on either side. The bed, therefore, really occupies about 39 inches, since the plants on the edges project 1½ inches on either side, thus making the bed a meter wide, the same as the conventional Dutch planting.

accomplished when the dirt is taken out in opening the second bed, the surface being left rough as the dirt falls from the shovel and smoothed off late in the season. The bottom of the second bed is then prepared for setting the bulbs, and the process is repeated with successive beds until the entire plat is planted. To facilitate the work the corners of the beds are marked permanently by stakes at the time they are laid off and these stakes serve as guides.

In laying off the ground careful attention is given to configuration, so that the drainage may be as nearly perfect as possible. Commonly the plats are marked off by the previous plowing, the back furrow being thrown into the middle of the land, thus draining into the dead furrow between the plats or lands. Where the subsoil is sandy, allowing the ready percolation of moisture, drainage ditches between the plats are not necessary, but in heavier soils it is imperative to make them. Even in sandy soils it is better that ample drainage be provided, because if the surface of the soil freezes there may be a time when water will be pocketed for a few days, to the injury of the bulbs.

FIG. 2.—Marking a bed with a homemade marker. The machine marks the rows, the outside, and the middle of the bed.

The bulb bed in the Netherlands is laid off a meter wide and of any convenient length—the width of the plat or land—preferably about 33 feet (10 meters). The plats are separated by walks 4 to 8 or 10 feet wide, which include the drainage ditches. In some instances narrow and wide walks alternate. Between the beds paths 12 to 16 inches wide are left. The rows run across the beds and are therefore a meter (39.37 inches) long. Our marker was made to lay off rows 6 inches apart. This marker is the same in principle as that used by the onion growers of southern Texas, being made of slats set in the periphery of an 18-inch cylinder 3 feet in length (fig. 2).

This handmade machine marks the row and the boundaries and center of the bed and is operated in the depression, which has previously been raked to a level. One marker does all the work, and

all rows are therefore 6 inches apart. The only variation occurs in the number of bulbs set in the row. Large bulbs are set 7 to the row; the second size, 9 to the row; and the third, 11 to the row. (Fig. 3.) These are commonly set upright and one in a place. The fourth size is planted 14 to the row, seven clusters, or hills, of two each, the bulbs being placed close together in any position in which they happen to fall. The fifth size is planted 21 to the row, seven clusters, or hills, of three each, the bulbs lying in any position. The sixth size is planted like the last—five in each of seven clusters or hills. Still smaller sizes are strung along about 50 to a row without any attempt at clustering. In practice, the number of bulbs of the last two sizes is only approximate, no attempt being made to count them. In the case of very large bulbs of hyacinths or of the Emperor narcissus, which can not be planted without crowding seven to a 6-inch row, a deviation is made in the spacing and the bulbs are set on the mark and half way between, making the rows 9 inches apart. Occasionally, smaller sizes of bulbs are strewn broadcast on the bed. This method, while simplifying the planting, makes digging much more difficult, for, instead of following each row across the bed with the digging tool, the operator must turn all the soil in the bed over to a sufficient depth to insure not cutting the bulbs and then must pick them out by hand.

FIG. 3.—Planting bulbs with a small crew.

This slightly modified Dutch method has not been much followed in this country except on the Pacific coast, and there it has recently been abandoned at Eureka, Calif., by Mr. Ward, who is experimenting with methods thought to be better adapted to the use of machinery. The bulbs there are set 2 inches apart in 2-foot rows.

In the Virginia bulb region (and a similar practice is followed generally on the northern Atlantic coast) the bulb beds are opened by turning furrows in opposite directions with a 12-inch plow. The dead furrow thus made is worked to a level with a cultivator, making a 15-inch bed, the path between being the same width as the bed. This is said to be similar to the Guernsey method. The bulbs are

covered either with the plow or with a winged cultivator which throws the dirt from the back furrow in either direction on the beds of set bulbs.

In the South Atlantic region bulbs are planted usually in 15-inch rows, the rows being opened with a 1-shovel winged cultivator. The bulbs are then set 2 or 3 inches apart and then covered by running a harrow over the ground. It is said that during the past two or three years an innovation has been introduced in some places in the Netherlands where a special 10-inch moldboard plow, having a triangular extension downward and outward, makes a depression the entire length of the furrow slice. The bulbs are set in this and the next bout covers the first row and opens another 10 inches from it.

DEPTH OF PLANTING.

About the first question asked by the novice relates to the depth of setting bulbs used in decorative planting. English writers dwell on

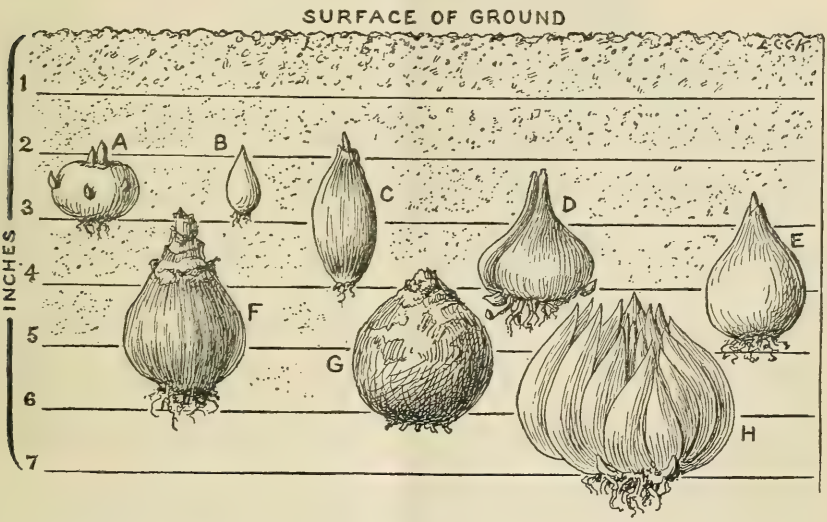

FIG. 4.—Sketch showing the proper depth to plant various kinds of bulbs: *A*, Crocus; *B*, snowdrop; *C*, iris; *D*, gladiolus; *E*, tulip; *F*, narcissus; *G*, hyacinth; *H*, lily.

this point and are explicit in their instructions. The accompanying diagram[1] (fig. 4) is a useful guide in planting bulbs for decoration. A common rule is to set the bulbs at a depth $2\frac{1}{2}$ times their diameter. Such a rule, while useful to the novice, will be little followed by one having experience with bulbs. He will know by intuition and will vary the depth with varying conditions. He will set his bulbs deeper in light than in heavy soil and in exposed than protected places. He will also set bulbs deeper in ground which heaves badly than in soil

[1] Adapted from Wight's Pictorial Practical Bulb Growing.

which has more humus in its composition. Likewise, the intended application of litter later in the season will influence the depth of planting.

In fact, the depth at which bulbs are set in commercial and decorative plantings is far from what occurs in nature, and they thrive at many varying depths. The point is emphasized in the case of many tulips which drop down 2 to 4 inches below the 4-inch level at which they are planted. It is not uncommon with us to have crocuses and tulips which are missed in the field come up the next season from a depth of 10 inches and flower perfectly. Indeed, there are indications that a great deal is still to be learned about the depth of planting, especially of tulips. There are accounts of tulips in Italy which have flowered perfectly for 12 to 15 years when planted a foot deep. There appears to be a correlation between deep planting and the permanent performance of tulips which are not shifted annually.

FIG. 5.—Removing the flowers before the petals fall in order to prevent seed production and the spread of the fire disease.

TREATMENT AFTER FLOWERING.

Little attention need be given to narcissus bulbs after flowering except that for the best results they should be kept free of weeds, like all other crops. With hyacinths and tulips, however, the matter is different. Here, it is necessary to remove the flowers, for the reason that there is an abundant seed production, which if allowed to develop would be at the expense of bulb growth. Again, with tulips it is imperative under certain conditions that no flower parts be allowed to fall upon the beds. Under seacoast conditions of humid atmosphere and heavy precipitation during the flowering season and immediately thereafter, the presence of fallen petals is very conducive to the development of the fungus Botrytis, the cause of the fire disease. It is therefore necessary in such situations to remove the flowers (fig. 5) before the petals fall. In varieties of narcissus which produce seed in abundance the removal of the flowers is, of course, advantageous.

ROGUING.

In the process of handling bulbs, mixtures are certain to take place to a greater or less degree. The laborer may be careless, or a bulb

may roll off of one tray into another, or when bulbs follow bulbs in the rotation the ones accidentally missed in digging and the droppers to a large extent may come up in subsequent years, all producing a mixture of varieties. To prevent these so-called "rogues" attention must be given at the time of flowering and they must be dug out. Were it not for the necessity of roguing when the flowers are fully open, other practices could be carried on in commercial work, such as cutting the flowers in the bud or not allowing them to open at all, and this would probably be a benefit to bulb production. However, in our work and in commercial work as well, certain benefits accrue in public appreciation which amply repay one for leaving the flowers until they begin to fade. This also allows the study and comparison of the different varieties, which in the rapid changes which take place in the relative merits of stocks due to constant improvement is all but imperative.

HARVESTING THE FLOWERS.

When there is a market for cut flowers from commercial bulb growing this is an added revenue. Indeed, in the Virginia bulb section the cut flower is the most profitable end of the business, and bulb production is purely secondary. The method of cutting the flowers is important. In the Virginia fields, where the stems of the narcissus, owing to the rather sudden advent of spring with attendant comparatively high temperatures, are short, the flower stem is pulled in gathering the flowers. In regions where the springs are cooler and the stems produced are longer they can be cut to better advantage, and this method is better for the bulb crop. In harvesting flowers from tulips, care must be taken not to rob the bulb of its leafage. In most sections it is not practicable to harvest tulip flowers for sale, except to a limited extent from the robust late varieties which have a foot or more of stem above the upper leaf. In removing tulip flowers after they have faded no leafage is destroyed, only the flower and 2 or 3 inches of stem being removed. The hyacinth spike of flowers is removed by severing the scape, or stem, with a knife.

There is a possibility that a by-product in the form of an essential oil may be made an added source of revenue here.

CULTIVATION.

There is no uniformity of practice in cultivating Dutch bulbs in this country. In the Netherlands the hoe and the hand serve every purpose after the plants appear above ground. The hoe for the paths and hand weeding for the beds are universal practices. It is difficult to use a tool in plantings of bulbs only 6 inches apart. In

the work at Bellingham, Wash., however, both a narrow-bladed hoe and a 3-tined hoe have been used with good success, the latter while the weeds are small and the former afterwards.

At Bellingham the beds are left rough at planting time. They are covered by the dirt as it falls from the shovel and are left untouched until the planting is finished, when the cultivation is begun by raking the beds smooth with a hand rake. This raking is kept up as soil conditions permit until the appearance of the plants above ground prevents it. After this, practically no cultivation is attempted, but hand weeding is practiced and the paths between the beds are kept free from weeds by the use of the hand or wheel hoe. Before digging,

FIG. 6.—Covering bulb beds in the Virginia region in late autumn with a plow.

the beds are hoed off to get rid of the old leaves as well as the remaining weeds. This practice is not satisfactory and is particularly expensive.

In the fields in Virginia, where bulbs are grown in beds 18 inches wide with 18-inch walks between, the practice is not essentially different from that at Bellingham, but there the bulbs are not dug more often than once in three years. In autumn and early winter in that locality the beds are covered by turning a furrow each way from the paths, thus covering them with 3 or 4 inches of soil. (Fig. 6.) Before the plants begin to push through in the spring the beds are gone over thoroughly with a spike-tooth harrow. After the tops die down the weeds are kept mowed and allowed to lie on the ground.

In the South, both horse and hand cultivation have been practiced, the bulbs being planted in rows 15 inches apart. There is little doubt that a method of planting and digging which will make possible the keeping down of weeds by some power other than the hand will prove decidedly advantageous. It is essential to get away from the practices of letting the weeds go after the plants are up, on the one hand, and of hand weeding after the plants are up, on the other.

FIG. 7.—Digging bulbs.

HARVESTING THE BULBS.

Harvesting the crop of bulbs is another rather tedious operation. (Fig. 7.) Thus far in the investigations of the Department of Agriculture this harvesting has been purely handwork. The operator works on his knees with a light, short-handled spade. In the Netherlands a flat hand trowel is used, a tool which is not serviceable in our heavier soils. The proficient workman operates this with one hand and throws out the bulbs with the other, while the novice requires both hands in using the tool, letting go with one to pick up the bulbs. A day's work in our silty soils consists on an average of about four 50-foot beds a day, and 50 to 75 per cent more on loose sandy soils. Tulip bulbs are put into small trays, which are shoved along the ground as the bed is dug. These are emptied into baskets or directly upon screen shakers (fig. 8), which sift out the greater part of the dirt. The bulbs are then transferred to the bulb house. Narcissi and hyacinths, except the smaller sizes, are dug like tulips, thrown into rows between the beds, and transferred to the bulb house later. The time allowed them to dry in this way will depend

FIG. 8.—A homemade shaker used to remove loose dirt from the bulbs after digging.

on the moisture present and the effect of the sun on the bulbs. Some varieties, and young bulbs especially, burn in a few hours and consequently must not be left exposed for any length of time.

In the Virginia fields the narcissus bulbs are plowed out, the 18-inch bed being split, one-half being turned each way. The furrow slice is then raked with a tined hoe, to pull out the bulbs. We are informed that since the war the Netherlands also has resorted to a 10-inch plow for digging, as in planting. There is no doubt that narcissi, especially the larger sizes, can be successfully harvested by machinery. In the department's operations a potato digger was employed one year, with rather poor success, though the writers do not feel satisfied that it received a thorough trial. The operation of planting unquestionably will have to be so adjusted as to permit digging by machinery in commercial operations.

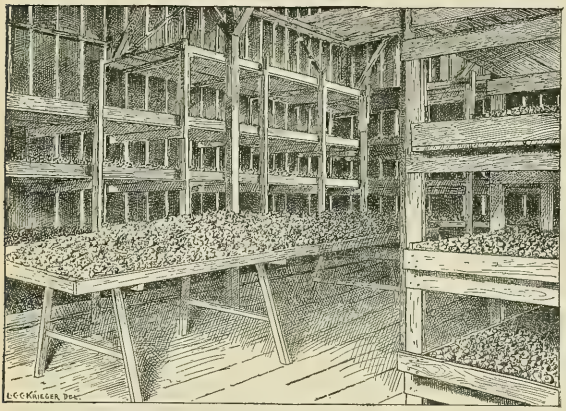

FIG. 9.—Temporary storage of narcissus bulbs in an old barn.

Various suggestions have been made, but thus far experience has approved no process of harvesting bulbs with machines. It is understood, of course, that the use of machinery in digging will necessarily change the method of planting, and virtually the entire scheme of operation. Both stationary and tractor engines have been suggested for power and a potato digger and plow operated by horses have been tried, but thus far nothing has been definitely decided for or against any power method.

STORING AND CURING.

Bulbs are stored and cured in specially constructed houses arranged with a view of getting the maximum of ventilation. The buildings are usually large and roomy, with doors (preferably in part of glass) reaching from ceiling to floor and occupying half of their walls. The interior arrangement of these houses varies. Sometimes they are equipped with stationary shelves a foot or more apart and about 3 to 4 feet wide, extending from floor to ceiling, with narrow alleyways between. (Fig. 9.) In other cases a stationary framework is built to receive removable trays. Occasionally this framework is constructed in units and is movable. Nurseries at Eureka,

Calif., are making their trays 3 by 9 feet and nesting them with the view eventually of handling by machinery a nest of 10 or more of these trays holding 3 bushels each. The Department of Agriculture has used both methods and prefers the tray which in the past has been 4 feet square. It is rather inclined to a 3-foot square, or possibly a 3 by 4 foot tray, for its purpose of handling a large number of varieties in moderate quantities. A 1-man tray may serve its experimental purposes better than one adapted to the handling of large quantities of fewer varieties.

The three classes of bulbs—tulips, narcissi, and hyacinths—require different conditions for curing. They are consequently best handled in different compartments of the bulb house. The treatment which each class receives with reference to ventilation will vary not only with the class, but also with the general atmospheric condition of the region in which the bulbs are grown. Curing under seacoast conditions will require very different handling of the ventilation from that 25 or even 10 miles inland. So variable and uncertain is this factor that experience under a particular environment is necessary before directions, except of the most general character, can be given. Experiences in handling tulips upon the grounds of the Department of Agriculture on Bellingham Bay and on those of private individuals in the Los Angeles region illustrate this fact. It is not at all unusual with us in a wet season to have small tulip bulbs on the shelves of the bulb house start to mold when only 2 to 3 inches deep. On the other hand, a grower near Los Angeles cured his tulips last year in burlap sacks. The bulbs were placed as dug in sacks about three-fourths full and tied as though filled. These packages were flattened out on the floor of the storehouse and turned over two or three times while drying. Such handling would be disastrous under the humid conditions at Bellingham.

Tulips go on the bulb-house shelves or trays as soon as they are dug, and always in thin layers. They should dry slowly. At Bellingham they are seldom dry enough to clean in less than two weeks, and it is quite possible that three weeks is the proper time for this process. During this period the bulbs should be kept well aerated, but free from draughts of air or wind and preferably not exposed to too strong light. When dry, the cleaning may begin and the bulbs returned to the shelves, but in deeper layers. After this, it should be the grower's care to keep the bulbs from drying too much, on the one hand, or molding, on the other. Much less air is necessary than during the drying process, and the light should be strictly subdued. In other words, the bulb house must be so controlled that the bulbs will not dry out too rapidly or be exposed to draughts or to too strong light. Any of these conditions will cause the bulb

coats to split. A dry, cool basement or half basement would seem to be an ideal place for such storage, but in a region adapted to bulb culture any building in which the ventilation is under good control will answer the purpose. In any location in such a building, except possibly close to the roof, where the temperature gets too high, bulbs can be cured successfully. After being cleaned the bulbs remain on the shelves in the bulb house until planting begins or until they are packed and sent to market. Sometimes the bulbs have been packed immediately after cleaning them, but it is better to leave them on the shelves and to box or sack the merchantable ones just before shipment is to take place. At times, when it is impossible to control light and air in the bulb house on account of being obliged to put tulips, narcissi, and hyacinths in the same compartment, it may be possible to cover the bulbs on the shelves with wheat chaff or buckwheat hulls. They keep very well in this way. Sometimes the shelves may be covered with burlap, or burlap curtains may be hung in front of the shelves.

FIG. 10.—Dug bulbs curing under litter from the beds.

Narcissus bulbs require less care in their handling than those of the tulip, but it is a very easy matter to injure them, too. When dug they are usually thrown into windrows in the field. In the absence of sun they can remain there for several days without injury. It has been the practice at Bellingham to let the larger bulbs have a few hours of sun, but in the Virginia bulb region it is said that two hours of exposure to the sun at midday are very likely to ruin many varieties. In the Netherlands it is a common practice to cover the windrows of bulbs with a thin layer of sand. We usually cover them with the litter hoed off the beds before digging. (Fig. 10.) When the bulbs are finally placed upon the shelves they may be piled thicker than tulips, but the thickness of the pile should be governed by the moisture content of the bulbs. They will withstand more aeration than tulips. It is for this reason advisable not to handle the two kinds of bulbs in the same compartment of the bulb house.

In practice, the curing, handling, and drying of narcissus bulbs are very likely to be done on a makeshift basis. In other words,

tulips and hyacinths receive the best care and attention, while narcissi take the space that is left. At Bellingham it has been the practice to cure and store these bulbs in an open shed, a purely temporary structure, wherein the protection is barely enough to keep off sun and rain. Indeed, at times, owing to lack of space, even tulips have been cured under similar conditions with fairly good success, but after cleaning they have always been stored in a more careful manner. The conditions at Bellingham are possibly rather favorable to such a makeshift treatment. A dirt floor constantly moist and the influence of the near-by coast tend to mitigate the evil effect of too rapid drying.

Hyacinths are allowed to remain in the windrow but a short time after digging, at most a day, and the small sizes not at all. The larger bulbs are well coated and protected with more or less dirt, so that in our situation they are not injured by a few hours' sun. They may be brushed lightly with a rough broom in the windrow and then put on the bulb-house shelves to dry. Experience shows that they need the airiest position in the bulb house, and on this account they should not here be stored or cured in open sheds with a dirt floor, though in many situations having a drier atmosphere such sheds might be sufficiently dry. As with tulips and narcissi, the aeration of the bulb house must be much more complete during the early stages of storing and curing hyacinths, on account of the large amount of superflous moisture. After two or three weeks in storage less air is necessary, but hyacinths require better aeration during their entire period of dormancy than the other two groups. The hyacinth is not only subject to molds in storage, like the other bulbs, but is prone to succumb much more quickly to storage rots, which are less prevalent when the bulbs are kept dry.

The temperature of the storage room must necessarily be variable and bear a direct relation to moisture conditions. It is probable that the protection of an ordinarily constructed house properly controlled as to ventilation will afford suitable storage conditions in any region where bulbs can be successfully grown. A stuffy, heated condition close to the roof, however, would be detrimental, and the opposite extreme of dampness in a basement, half basement, or lower floor should also be avoided. In short, a bulb storage house requires daily attention. No formula can be given for its handling. The grower must study his conditions and become sufficiently conversant with the subject to know what to do when the conditions in any portion of the house are not what they should be. The latitude in temperature permissible in storage is indicated by Dutch practices with bulbs that are habitually subjected to artificial heat in order to hasten certain processes which take place during the dormant season. A distinct

class of bulbs, based upon this artificial heating, known as "Dutch prepared," has been on the market for some years. These are nothing more than bulbs whose development has been forced by artificial heat while in storage.

Very fundamental changes take place in bulbs while they lie "dormant" on the shelves. Should one cut a large tulip bulb open through the growing point upon digging, as soon as the leaves have died down, he would probably be disappointed in not being able to find readily the flower bud; but by September 15, unless low temperatures have been maintained, the flower will have developed to half the length of the bulb, and by the first of November the flower may be actually protruding through the tip of the bulb. All this growth has taken place in storage and is of tremendous importance to the consumer, the florist, and the producer of bulbs, for future behavior is largely influenced by these changes which take place in the bulb house. The higher the temperature during storage the more rapid is the development of the flower spike; consequently, the shorter the time necessary for it to come into blossom. A long period in storage produces similar results, so that a region which is able to dig its bulbs early will have bulbs that can be forced earlier than where they mature later and are consequently dug late. This fact is well brought out in comparative forcing tests of stocks grown in the Netherlands, in Bellingham, Wash., and in Eureka, Calif. Bulbs from the last-named locality are the earliest and the Holland-grown bulbs the latest to flower. The time was when our early forcing stocks were grown almost entirely in southern France the year previous to their importation. Now earliness is brought about in Holland-grown (late-dug) bulbs by a process of forcing in storage. The indications are that, by the selection of the locality, we can produce in this country the equal of the "Dutch prepared" or French stocks without resorting to artificial processes.

This all means that to the commercial grower the temperature of his bulb house will be such as is natural in the region from July to October, coupled with proper moisture control, and that the higher the temperature the shorter the time the bulbs can be held out of the ground, for after the flower begins to push out of the bulb deterioration takes place very rapidly.

CLEANING.

As practiced in the Netherlands cleaning is one of the tedious processes of bulb culture, as it is hand labor exclusively. A great deal of it, however, can be accelerated by the aid of simple machinery. When one has but few bulbs the operation may be done by hand, but with lots of several thousand bulbs simple devices are time savers.

In the work of the Department of Agriculture at Bellingham, tulip bulbs are placed in boxes, which are moved along by the digger. No effort is made at this time to get rid of the dirt. About a bushel of the bulbs are then shaken lightly in a homemade shaker which has a quarter-inch wire-mesh bottom (see fig. 8), and the loose dirt is thus removed. After drying, the bulbs are taken from the shelves to tables and picked over by hand. This process consists in breaking the clumps of bulbs apart and removing the old scales and bases. Of late, much labor has been saved by passing the bulbs over a 5-centimeter to 7-centimeter screen before hand picking. All the smaller loose bulbs and some scales and dirt are thus eliminated. These bulblets are then passed through a blower (fanning mill), when they are ready for planting, the large bulbs and clumps (fig. 11) being the only ones worked over by hand. This simple device of sieving out the smaller sizes reduces the handwork in cleaning tulips nearly one-half. The sieves used are made of parchment, and the blower is padded with canvas to protect the bulbs. Extreme care is necessary in all of these operations lest the bulb be bruised.

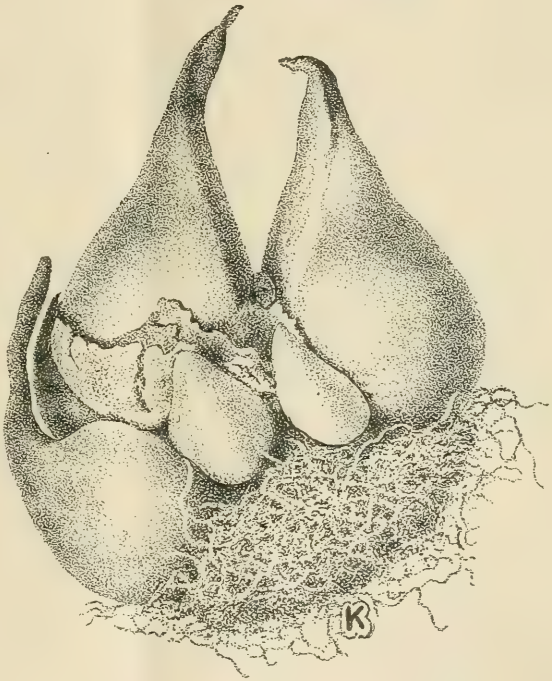

FIG. 11.—Bulbs of a Darwin tulip, showing a normal reproduction of two flowering bulbs and four smaller ones.

Narcissus bulbs, except the smaller sizes, which go into the bulb house immediately on being dug, are thrown into windrows, allowed to dry a few hours, and then covered with débris to prevent injury from the sun. Later they are sieved, like the tulips, and placed in the bulb house or in open sheds on trays or shelves. After the roots are dry the bulbs are worked over by hand to break the clumps apart. In some cases the roots are pulled off also, but it is questionable whether anything is gained in taking time for this. There was a time when the narcissus bulbs which were imported into this coun-

try were thus carefully cleaned, but this practice has been abandoned for the past two or three years.

Much time may be saved in the handling of narcissus bulbs by a little judicious planning based on the characteristics of each variety. As an example, when the bulbs of the bicolor Empress are on the cleaning tables, the easiest way to handle them is to break off and throw to one side, by hand of course, the increase, leaving the large bulbs on the table to be handled later with a shovel. With bicolor Victoria, however, where there is likely to be a large number of small bulblets, the easiest way is to pick out the large bulbs by hand and leave the small ones on the tables, to be shoveled up later and put through a blower to take out old scales and other extraneous matter. In the same way, the characteristics of the different varieties must be taken into consideration in handling the bulbs expeditiously. This is as true of tulips as of narcissi. The cleaning of the Cardinal's Hat variety should be done very differently from the Proserpine or Double Early Titian.

Hyacinths when dried are gone over carefully by hand, mainly for the purpose of culling rather than cleaning and separating them, for there is no splitting in the ordinary propagation of these bulbs. The main process of this kind occurs the first year, when the bulblets are separated from the mother-bulb clump. Often the older bulbs are left to lie in the rows for a day and then are swept with a broom before being put on the shelves. The smaller sizes, however, go directly to the bulb-house shelves, like tulips. The most difficult job of cleaning in the case of the hyacinth occurs the first autumn after propagation. At this time the bulblets come out of the ground in a clump interlaid with the old bulb scales, which still hold together more or less tightly. Usually the separation of this clump is done entirely by hand, each bulblet being picked out individually. This work can be very much simplified. The clumps must be broken up by hand, though it is not necessary to pick up the bulblets individually; but after the separation the whole mass can be put through a good blower (a fanning mill properly padded), when the stock will be rendered ready to plant. After the first year the work on the bulbs in the bulb house need consist of only a "pawing over" the shelves to pick out imperfect and diseased and rotted bulbs.

SIZING.

The Dutch grower, with high-priced land and low-priced labor, probably sizes his bulbs closer than the commercial grower in this country ever will. In the work of the Department of Agriculture the sizing has been rather closely done also, and, indeed, the Dutch methods have been employed in greater part with most of our work.

The sizes of bulbs as employed in the descriptions of commercial varieties are likely to be confusing to an American, for two reasons: (1) The metric system is used, and (2) the listings are for bulb circumference instead of diameters, as practiced with freesias in California. Since all business is done on this basis the prospective bulb grower must accustom himself to these terms. Indeed, the matter is not really complicated. The sizes of foreign-grown bulbs are always given in centimeters, abbreviated to "cm." To translate the centimeter into inches one needs only to divide by 2½. This gives the circumference in inches. If one wishes to arrive at the diameter, a further division by 3 will give the approximate result. For instance, a 15 cm. bulb will have a circumference of 6 and a diameter of 2 inches.

The sizes of bulbs as used in commercial culture vary with each grower, and even may vary from year to year with the same grower, depending upon the land available, the fertility of soil, and other factors. In short, his grades are matters of size, and size is a matter largely of convenience and varies with fertility, age, variety, etc.

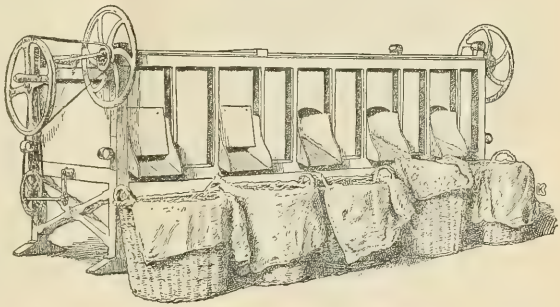

Fig. 12.—A bulb sizer used extensively in the Netherlands.

In the work of the Department of Agriculture approximate sizes have been adopted. These relate entirely to the growing end of the business and do not enter into commerce. The sizing thus far has been done mainly by the conventional circular nesting sieves of the Netherlands. These have parchment screens and are operated by being shaken in the hand or, when nested, in a hand shaker, several sizes then being sorted at once. This method works well for small quantities of bulbs. For large quantities other forms of machines are in use. One recently constructed is a revolving drum of parchment, its operation being not essentially different from a gravel screen. The most commonly used machine, however, consists of an oscillating plane made up of a series of sieves placed end to end with suitable chutes on either side to receive the different sizes. (Fig. 12.)

This matter of sizing machinery will require the attention of implement manufacturers, and there is little doubt that the need will be met as the occasion demands. The essentials are separating sieves, an operation that will not bruise the bulbs, and a good blower.

The parchment screens are made with perforations 3 to 24 centimeters in circumference. In the sizing of tulips we have employed

mostly the 13, 12, 10, 7, and 5 centimeter sieves, those bulbs caught by the 13-centimeter sieve being designated as size 1, those caught by a 12-centimeter sieve as size 2, etc. This gives six sizes, the last being those bulbs passing through the 5-centimeter sieve. Again, with tulips we employ another size, designated as "toppers," which are occasionally taken out by a 14-centimeter sieve. This size, however, is seldom used except when it is necessary to keep the larger bulbs of some varieties for propagation at the time the stocks are disposed of.

The separation of narcissus bulbs is accomplished by the use of the 16, 14, 12, 10, 7, and 5 centimeter sieves, the first size being the largest bulb. In the sizing of hyacinths the same sieves are used, plus an 18-centimeter sieve, which here is designated as size 1.

ADVANTAGES OF SIZING.

The sizing just specified, as stated elsewhere, is purely a matter of private concern and does not enter into commerce at all, being merely for the use of the grower. The only object served in this close sizing is to facilitate planting. It enables the grower to distribute plant material evenly over his ground, thus securing the maximum of economy. A grower will have bulbs of several sizes of one variety and, of course, will plant the smaller bulbs more thickly than the larger ones.

In practice, it is seldom that one variety is separated into as many sizes as have been listed here, but in order to illustrate more fully the use of sizing let us suppose that a variety of narcissus, for instance, has been so separated, that the land is laid off, the first bed opened, raked down, and marked, as described elsewhere. The largest sized bulbs will then be planted 7 to the row across a conventional 3-foot bed; the next size, 9 to the row, and the third size, 11 to the row. These, with us, are all planted singly, uniform distances apart, and set upright. The fourth size, or that caught by a 10-centimeter sieve, will be planted 14 to the row, but in seven clusters of two each, the bulbs in any position they happen to be. The next size will be planted similarly, three in each of seven clusters. The sixth size is again similarly placed in seven clusters of five each. The seventh, or smallest size, is planted 50 to the row, the bulbs being drilled uniformly along the 3-foot mark.

CULLING.

One of the most important operations—in reality a series of operations—in bulb culture is that of getting rid of undesirable plants. Successful bulb culture must be a constant process of selection or the reverse, elimination, for it is only by constant elimination of the undesirables that the stock can be kept up. The large amount

of handwork involved contributes directly to the possibility of doing a large part of this culling.

The time when culling can be done to best advantage is while the bulbs are in the bulb house. At this time all imperfect and questionable individuals should be ruthlessly rejected. No stock should be planted which is under suspicion of disease. On the other hand, especially while the grower is working up his stocks, it is necessary to distinguish between imperfections which will result simply in a reduced yield and those which may cause contamination. For instance, a skinned tulip bulb, even when slightly moldy, may and probably will produce perfectly healthy, although smaller, bulbs than those planted. A healthy reproduction may often occur even when there is no top growth. Consequently, it may be highly desirable often to plant bulbs which are of very bad appearance, provided they are not infested with a noxious disease or with insects. Such tulip bulbs will produce again. Narcissus bulbs affected with the narcissus fly, however, should be destroyed wherever found; but, even here, one bulb of a clump affected by the fly does not reduce in the least the value of the other bulbs.

FIG. 13.—Narcissus bulbs, showing a good propagation in the Sir Watkin variety.

This process of culling should be going on constantly. Beds should be rogued at blossoming time, weak plants should be destroyed during the growing season, and bulbs of poor quality or found to be infested should be culled out of stocks either in storage or in the field whenever and wherever detected.

PROPAGATION.

All of the classes of Dutch bulbs described in this bulletin can be propagated from seed, but this form of reproduction is used only by the breeder.

The writers prefer to plant the seed in the autumn in a well-prepared seed bed in a coldframe. The seed should be put in one-half inch deep and mulched with litter, which is removed before the growing season opens. Special care should be exercised to see that there is a constant supply of moisture, so as to prevent the seed from drying out at any time.

Tulips, narcissi, and hyacinths reproduce naturally in another way also. Upon reaching maturity the bulbs divide into two or

more (figs. 11 and 13), which are removed and grown to flowering size. The degree of splitting varies greatly, even in members of the same genus, and is modified by both cultural and handling methods. In practice, this is the commercial method of increasing the stocks of tulips and narcissi, and to some extent of hyacinths. The reproduction of the narcissus by this method will mean approximately a doubling each year. In the case of Darwin tulips about an 80 per cent increase each year may be expected, and in single early tulips a little less than this. So many factors are involved that it is very difficult to give exact figures.

While the propagation of the Roman hyacinth is essentially the same as that of the narcissus, the Dutch hyacinth is reproduced by a

FIG. 14.—A scooped hyacinth bulb ready to be planted after in incubation period of three months in artificial heat.

FIG. 15.—A scored hyacinth bulb ready to be planted after an incubation period of three months in artificial heat.

very artificial process. It consists essentially of the destruction of the growing point of the bulb, causing the development of many growing points on the callused edges of the severed scales. Two forms of this artificial reproduction are practiced. One known as the "scooping" method (fig. 14) consists of cutting out a convex section of the bulb base, removing the basal plate entirely and making the cut parallel to its upper surface. This is done with a curved scalpel or a round-bowled spoon sharpened on the edges. The other, known as the "scoring" method (fig. 15), consists of making two to four cuts with a sharp knife across the base of the bulb, each cut being the diameter of the circular base and passing entirely through the basal plate and intersecting the other cuts in the growing point, which is destroyed.

It is a common practice to dip the cut surface of the scooped bulbs in a little air-slaked lime mixed with dry sand to hasten their drying

and prevent the growth of molds. As soon as the bulbs have been prepared by these methods they are placed in a room in which the temperature and moisture are under control. Some withhold heat for a time, simply keeping the bulbs in atmospheric temperatures; others apply a little heat immediately; but in either case a comparatively dry atmosphere is essential until the cut surfaces are callused. This takes from 10 days to two weeks. Too rapid desiccation during this period, however, must be avoided, or the center of the bulb will be injured. After callusing, the bulbs are kept in an artificial temperature and a high humidity for about three months. The temperature will vary widely, between 70° and 90° F., the object being to get a maximum development of bulblets without causing the bulbs to be forced into excessive leaf growth.

It is a common practice to bury the scored bulbs under ordinary field conditions for 10 days or two weeks and then bring them into the propagating house (fig. 16).

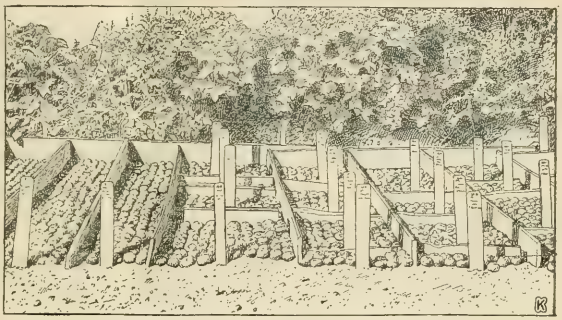

FIG. 16.—Scored hyacinth bulbs set in the open ground ready to be covered with earth preparatory to being propagated in ten days or two weeks.

At the end of the period of incubation, which will be early October, the propagated bulbs are planted in the same way as untreated bulbs.

The rate of increase will vary not only with the method of cutting the bulbs, but also with the variety. Scooping gives a comparatively large number of uniform small bulblets, while the scored method produces a smaller number of bulblets much less uniform in size but much larger. The former method is much more favored on account of the more uniform progeny, but it requires a longer time to bring the bulblets to maturity. In practice, all bulbs with perfect round bases are scooped, while those of such a character that they would not hold together if the bases were cut out are scored. In scored bulbs an average of 15 bulblets would be considered satisfactory, as would 35 in scooped bulbs, but the number of bulblets may run as high as 30 with the former and 60 to 100 with the latter treatment.

One decided advantage of scooping is its usefulness in detecting diseases. By this method the base of each scale of the bulb is exposed to a clear view when the basal plate of the bulb is scooped out. If any doubt exists after this it is customary to nose the bulb also. This consists in cutting off a small portion of the tip of the bulb as well, thus

exposing the live tissue of both ends of many of the layers. This gives a very effective check on both yellows and nematodes, the causes of the two serious maladies of these bulbs.

The building suitable for propagation is a simple affair in which heat, moisture, and ventilation are under control. At present the department's work is done in a boarded-up room in the basement of the bulb storage house, in which has been installed a hot-water heating system. Light seems to be a factor of little consequence, except that provision should be made for good artificial light for use when examining the bulbs. At present most houses in the Netherlands are constructed without glazing. We have good success also without lighting.

The bulbs are supported upon trays with wire bottoms, which are arranged in racks at distances of about a foot apart. Chicken wire stretched over frames about 3 feet square answers the purpose very well. This permits the freest circulation of air around the bulbs.

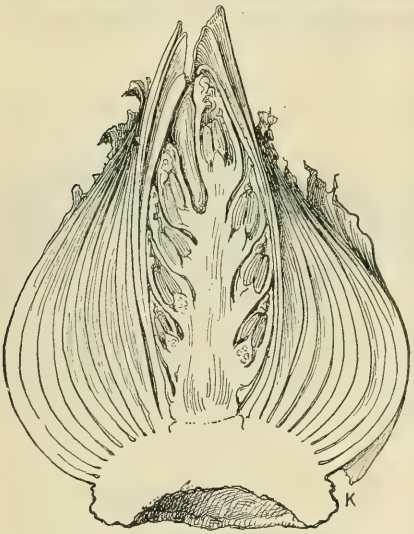

FIG. 17.—A mature hyacinth bulb cut open to show the well-developed flower spike at the time of planting.

DETERMINATION OF FLOWERING QUALITY.

For our purposes a bulb may be looked upon as a condensed plant which contains the evidence of its qualities within itself. The grower in his planting, but more especially in his selling, must be able to decide with a great deal of accuracy just what bulbs will flower the succeeding year. This ability is gained very largely by experience, but certain indications can be learned in the abstract.

The bulbs of the tulip, narcissus, and hyacinth have within them, perfectly formed, the flower spike for the next year's blossoms, and by the sacrifice of a few bulbs one can get a very good idea of the quality of the bulbs before they are planted.

Hyacinth bulbs are utilized for ornamentation from about 12 centimeters upward, the miniatures being usually about this size. They will flower at a much smaller size, but the number of bells will be progressively more numerous and larger as the bulb increases in growth. (Fig. 17.)

In the case of the narcissus the varieties are so variable in the size of the bulb that for the uninitiated the safest plan is always to

dissect a few bulbs. A single case will illustrate the difference in behavior. In bicolor Victoria at Bellingham in 1917 an 11-centimeter bulb was required to insure flowering the next season. Below this, three or four sizes could be separated with ease. In the Sir Watkin variety many bulbs passing through a 7-centimeter sieve would flower. There is little difference in the size of the full-grown bulbs of these two varieties, although they are very different in appearance.

The tulip, on the other hand, bears indications of future performance on its exterior. Besides the size indication, there are still others. In the department's work tulip bulbs caught by a 13-centimeter sieve have been recognized as the first commercial size and those caught by a 12-centimeter sieve as the second size. Both of these are flowering sizes and merchantable bulbs. Beyond these, there is still another size taken out by a 14-centimeter sieve, which is designated "toppers." This class the commercial grower usually should not sell but use as propagating stock, for it is here that he gets his strong and numerous progenies, and by using these toppers the grower is constantly conducting a selection of value. It is not to be understood that sizes smaller than 12 centimeters will not flower. Far from it, for bulbs as small as 8 centimeters in size could be picked out which will flower well, especially of such varieties as the Artus and the Sir Thomas Moore.

It is to be taken for granted that bulbs of the same size in the same variety will have practically the same flowering qualities, especially if produced under the same conditions. If, then, when a certain size of bulbs has been segregated it is found that some of them flowered the current year the assumption that all will flower the next year is justified. The bulb of every tulip which flowered the current year bears the evidence of it on its front side. If the base of the old flower stalk is not present, a groove marking its position is always discernible.

The bulb which will flower next year but which did not flower the current season can always be recognized by its more round appearance and long neck. Previous to flowering the bulb of a tulip produces a single but very strong leaf, the base of which is continuous with the outer coat of the bulb. A portion of this leaf base persists, forming the long neck.

A word of caution is necessary regarding attempts to determine the flowering quality of bulbs by cutting them open. Here, the consumer of bulbs has a decided advantage over the producer. As has been stated, the flower bud develops wonderfully in storage. The uninitiated may arrive at an entirely erroneous conclusion if he dissects them even late in the season when they have been held at a low temperature, but under ordinary conditions there should be no difficulty in finding the flower at planting time.

PACKING BULBS.

Bulbs in large bulk are prone to sweat and are easily bruised and mashed against the sides of the containers. For these reasons it is necessary to make shipments in some fine packing material that will sift in between the bulbs. Several substances are employed for the purpose, but grain chaff is most commonly used. Buckwheat hulls are preferred to all other materials, and rice chaff is a close second. Wheat chaff and chopped straw, while usable for a moderate time, are inclined to absorb moisture under moist atmospheric conditions. Sawdust has at times been employed, but has not always proved satisfactory. It is better when old and weathered, especially if free from turpentine and thoroughly dry. Redwood sawdust would probably be much better than other kinds, but the writers know of no experience with it. In some instances peat and finely broken up sphagnum have been employed.

Tulip bulbs are commonly packed in paper bags containing about 250 and the requisite quantity of hulls and then are shipped in crates holding 2,000 to 5,000 bulbs. Hyacinths are handled in much the same way as tulips, and so also are many varieties of narcissus, but the commoner, hardier varieties of the latter are more often forwarded in slatted crates holding 2,000 to 5,000 bulbs or more, with no packing materials. Sometimes hyacinths are forwarded in the same way.

Since 1917 the shipping of bulbs from the Netherlands has been attended with many difficulties, and they have arrived in all sorts of conditions. Probably owing to the difficulty of securing packing materials, but little was used. Hundreds of cases were a complete loss, and the commoner narcissus, which is usually shipped without packing, appeared to suffer about as much as the tulips and hyacinths. Indeed, tulips, mostly without packing material, have come through in the past two years in good condition. Much depends upon the position of the cases in the holds of the vessels and the length of time in transit. A large unaerated package is dangerous with any bulbs, since some heating is bound to occur; consequently, root action starts and very soon decomposition sets in.

SHIPPING BULBS.

The experience of the Department of Agriculture in the shipment of the bulbs of both the tulip and narcissus has been uniformly satisfactory. The latter have been shipped in citrus crates without packing. Tulips were put up one year in cloth sacks packed with buckwheat hulls, about 250 to the sack, and crated in slatted crates holding about 20 of the sacks. The past season 125,000 tulips were put up loose in buckwheat hulls in tight wooden boxes holding about

1,000 bulbs each. The stocks were well cured and came through by the northern route from Bellingham, Wash., to Washington, D. C., in perfect condition. Some of them were left in the boxes for two months, but at that time the packing material was slightly discolored, showing that this was about the limit of their endurance in these tight packages. They would not stand it as long, of course, by the southern route. The citrus crate for narcissi is satisfactory, provided there is no handling en route. Where there is any handling or shifting of the load it is too light. In car lots with little handling, however, the package is ideal, as the crate insures sufficient aeration.

BULB GROWING FOR PLEASURE.

Little need be said regarding bulb growing for pleasure, for the subject is a popular one and it has been covered so often and so well that little can be added. Naturally the purchaser of bulbs in a small way turns to the catalogues of some reputable seedsman who imports in large quantities for each autumn's distribution. Long experience has crystallized the cultural directions given in these publications. Some firms issue general directions covering all classes of bulbs, which are most valuable compendiums of information. Besides these there are plenty of publications which treat the subject exhaustively. (See page 47.)

OUT-OF-DOOR CULTURE.

In out-of-door decoration the average man uses bulbs in quantities of dozens or hundreds, planting them in formal beds or placing them carelessly in clumps, in borders among shrubbery, etc., where the result is more pleasing than in formal arrangements unless the beds are extensive enough to give a mass effect. An endless variety of effects is obtainable, depending upon individual taste, the disposition of other plantings, the configuration of the land, the exposure, and many other factors. Most landscape artists advise distributing bulbs in clumps of a half dozen to a thousand or more, depending upon the size of the grounds and the effect desired. A maxim that can always be kept in mind is that there is always the danger of not planting enough and seldom of planting too many.

To simplify directions, it is safe to cover the bulbs of the narcissus, tulip, and hyacinth 3 to 4 inches to the top of the bulb and to mulch all of them, except tulips on humid coasts where the fire disease is likely to be prevalent. Here, even, the flowers of tulips should be cut off before the petals drop, and clean culture should be practiced.

The naturalizing of the narcissus in grassy places and among shrubbery, etc., is an exceedingly attractive venture, many varieties

succeeding admirably when handled in this way. The bulbs are set with a dibble, trowel, or mattock. Usually, if time permits, it is better to remove the sod and give the ground a good digging, and, if naturally poor, fertilizer deeply incorporated is added. Regarding fertility it may be said that good garden soil is well adapted to the narcissus, but one will commonly succeed better in lean soil than with one loaded up with manures. Under the latter condition bulbs are likely to decay, even though the manure may be what is commonly termed "well rotted." We in this country have not yet acquired the habit of spading our ground two spades deep, as they do in foreign countries, thus putting our manure 3 to 6 inches below the bulbs. This kind of treatment on lean soil would furnish ideal conditions for the longevity of narcissus bulbs.

Narcissus beds and borders will usually improve if left alone until about the third or fourth year and then will deteriorate gradually. In grass where they have greater competition with other vegetation the multiplication is not so rapid and the crowding of the progeny is longer deferred, and if the variety is well adapted to this treatment it does not occur at all. Crowding can also be delayed by planting bulbs of the smallest size that will flower. The commercial bulbs of the second size are very suitable, but under no condition should double-nosed bulbs be bought if intended for permanent plantings. The narcissus in grassy places must be left undisturbed each year until the foliage begins to turn color well in the first half of June, then mowing can take place. The grass will have headed out by this time, and it will be necessary to go over it with a sharp scythe before the mower will do good work.

Better success usually will be had with tulips and hyacinths if they are lifted each year at the time the foliage matures. If second or third sized bulbs are planted, however, they will give good results the second year and will be satisfactory even the third year, while occasionally they are reported as successful even longer than that. Usually, however, tulips and hyacinths should be lifted each year. With the tulips, as with lilies and crocuses, there is the added danger from mice, which are very fond of the bulbs and destroy quantities of them when left semipermanently. There is much less danger from this source when the ground is thoroughly dug, thus destroying the runways of the mice in the autumn, and the bulbs are dug again in June.

In formal beds it is usually necessary to remove the bulb crop after flowering, in order that other bedding plants may be inserted. Commonly the bulbs are rooted out and thrown away, but this practice is simply another wasteful American habit that should be discontinued. The bulbs should be carefully lifted with as little injury as possible to roots and leaves and heeled in in some good situation,

to continue their development until digging time. If the job is carefully done the resultant bulbs will be but little inferior the next year, while in regions adapted to the production of bulbs if given a year of proper treatment they will entirely recover.

It is often possible and desirable to use carpeting plants, such as pansies, arabis, and phlox, to add to the mass of color or to prolong

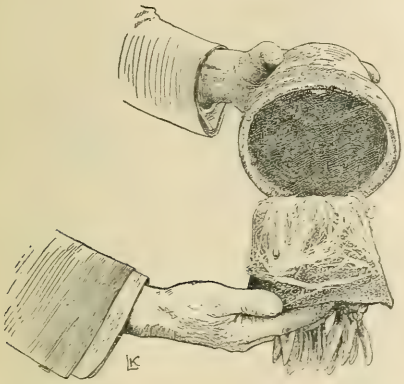

FIG. 18.—A pot of hyacinths showing the right kind of root development at the time they are brought into full heat.

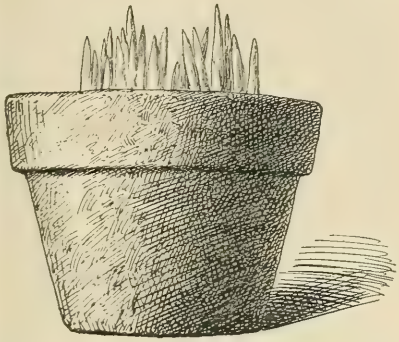

FIG. 19.—A pot of crocuses showing the time they are brought under forcing right kind of top development at the conditions.

the season, when the bulbs may be allowed to ripen in place and be lifted, and still later bedding plants may be put in. If the bulbs are set deep it is quite possible to spade or fork the ground shallowly without disturbing the bulbs and to grow any shallow-rooted crop for ornament or profit. We have known cowpeas to be planted to improve the soil and keep down weeds. These can be put in between the plants after the flowers have faded.

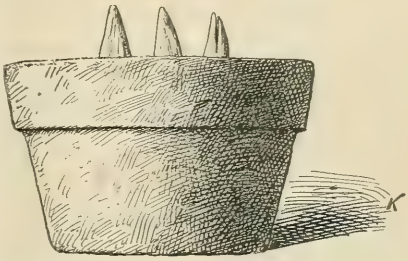

FIG. 20.—A pot of hyacinths showing a minimum of top development at the time they are taken out of the heeling ground.

INDOOR CULTURE.

While the florist successfully forces millions of narcissi, tulips, and hyacinths each season to supply the cut-flower market, the housewife fails as often as she succeeds with bulbs in the house. If, however, a proper selection of bulbs is made and certain requirements obtain, which are possibly more easily stated than found in an ordinary home, success will be assured. There are three conditions to be met. The first is to root the bulbs well before bringing them into heat (figs. 18, 19, and 20); the second, to keep the temperature down;

and the third, to keep the atmosphere moist. A little experience will enable one to meet the first condition, but our American homes are usually both too hot and too dry for the best growth of bulbs. The heat requirement can be met by selecting, preferably, an east window away from radiators or heating pipes; by covering the soil in the pots with either commercial moss or living moss from the woods greater evaporation will be induced. Avoid haste to get the flowers into blossom. Indeed, very good advice to one without experience is not to attempt to bring forced bulbs into flower earlier than the middle or, better, the last of February. As experience is gained the time can be shortened. Another good piece of advice is to give the bulbs not less than eight weeks for rooting and then to bring them into a cool cellar and introduce them to heat gradually.

Good garden soil will generally be used by the housewife for pots containing bulbs. Well-rotted manure and sand or decayed turfy loam and a little bone meal may be profitably employed if the garden soil is poor. It should be borne in mind, though, that the three conditions just specified are of even greater importance for the flowering of the bulbs than an abundance of plant food, which is of more service in building up the bulbs for the succeeding year's performance.

After the bulbs are potted they are usually buried out of doors or covered with earth, litter, ashes, etc., for a period of 8 or, preferably, 10 weeks, where they will be kept cool and moist and prevented from freezing. When the roots are sufficiently developed they are brought into a cool cellar for 10 days or two weeks and then into the living room, thus coming into heat gradually.

In writing directions for amateur bulb growers it is customary to insist on good drainage in the pot culture of bulbs in earth and then in the same breath to advise growing them in water without any drainage. This latter method is successful with many varieties. To assist in keeping the bulbs in place in bowls in water without drainage, gravel, pebbles, coal, or sphagnum moss are used, and it is desirable to add charcoal and crushed oyster shells or a little coarsely ground bone. After the roots begin to form, the bowl is easily inverted by holding the hand under it to drain out the water. This change of water should take place weekly at least. The same precautions are necessary to have the bulbs well rooted before they are brought into heat. The rooting can take place in a cool dark cellar, attic, or any other suitable and convenient situation. The plants most commonly grown in this way are the Chinese sacred lily, Paperwhite narcissus, and hyacinths, although many varieties of tulips and species of other genera succeed. It takes more experience and care to force tulips than varieties of the other two genera.

The commercial forcing of bulbous stocks need not be considered here, for the grower will refer to the columns of the trade papers, where special departments in charge of experts keep growers informed of the most approved methods of handling bulbs, based upon long experience.

MISCELLANEOUS BULBS.

Besides tulips, narcissi, and hyacinths, scores of other bulbous stocks are offered for sale as Dutch bulbs. They are of easy and profitable culture and can be readily grown by methods similar to those employed with the others. Importers and seedsmen handle some or all of them each autumn, and some of the varieties are within the reach of all. Some of these groups deserve a bulletin to themselves. All of them can be produced in this country. Of those which are especially easy of culture the following may be mentioned: Chionodoxa (glory-of-the-snow); eranthis (winter aconite); crocus; anthericum (St. Bernard's-lily and St. Bruno's-lily); galanthus (snowdrop); Spanish, English, Dutch, and oncocyclus iris; Helleborus (Christmas and Lenten roses); montbretia; muscari (grape hyacinths); scilla; camassia; leucojum (snowflake); puschkinia; triteleia; ornithogalum (star of Bethlehem).

BULB PESTS.

During the past 10 years the Department of Agriculture has imported Dutch bulbs annually. While an effort has constantly been made to get clean stocks, there has been no way of compelling compliance with its injunctions in this respect. So far as can be determined the stocks secured have been no better than the ordinary commercial importations. It is believed, therefore, that we have had a good chance to get all the maladies to which bulbs are heir. This brief statement given here relates only to those maladies with which we have had to deal.

INSECTS.

For years the most talked-of bulb pest has been the narcissus fly (*Merodon equestris*). This insect can be detected late in autumn by the "feel" of the bulb, the affected bulb being lighter in weight than the healthy ones and soft. If squeezed between the thumb and forefinger the larva, or maggot, half an inch in length and a trifle less than one-fourth inch in diameter, will commonly be forced out of the neck. Usually but one maggot is in a bulb. If late planting occurs there is an opportunity at that time to pick the bulbs over and destroy those affected. Again, in early spring, as the plants are coming through the soil and up to the time they are 4 or 5 inches high,

affected bulbs can be distinguished with a considerable degree of certainty. Weak plants or those failing to come at that season can be dug out and destroyed. This is not a difficult task, and at this time a few days spent in going over the beds will pay big dividends. The time for doing this work, however, is short, as the larva leaves the bulb for the ground shortly after the plants come up. This method of detection of these flies is applicable only when annual lifting is practiced.

Another common insect, which inhabits not only the narcissus but tulips commonly and hyacinths and scillas less frequently, is the lesser narcissus fly (*Eumeris strigatus*). In digging the weak bulbs in the spring, particularly if they contain bulbs decaying from any cause, the larva, or maggot, of this insect is likely to be more prevalent than that of the other. It is a small yellowish white maggot, somewhat larger than that of the ordinary house fly, and several to a score or more may be found in a single bulb. When first encountered this discovery is likely to create great alarm, but it is questionable whether this fly really does injury. The evidence in the literature from British sources seems to indicate that the insect is saprophytic and follows when the bulb dies and decays. One caging made at Bellingham seems to substantiate this view, since the insects failed to attack healthy bulbs.

FIRE DISEASE OF THE TULIP.

The tulip with us has been remarkably free from serious pests. But one disease of consequence has appeared. This is the fire disease, caused by a mold (*Botrytis parasitica*). This ubiquitous organism is always with us at Bellingham, and no doubt some injury is done by it. It is more prevalent upon the Darwins than any other variety, their leaves and petals being nearly always affected to some extent, but never very seriously so far as the general variety is concerned, although we have been alarmed some seasons. The season of 1916 was no exception, nor was that of 1917, but the same stock which was affected both years at Bellingham was unaffected when grown in the District of Columbia in 1917 and was reported without infestation at Eureka, Calif.

We are now on the immediate bay shore and are of the opinion that 3 miles back from the coast we will suffer less. Humid conditions and the presence of decaying organic matter, such as fallen petals, contribute to the development of the mold. It is claimed that it is for this reason that the bulb growers on the other side of the Atlantic are loath to permit any litter on their tulip beds, although they use it very freely on narcissi and hyacinths. Hail injures the leaves and assists in inoculating the plants. In the District of

Columbia a planting of 400 bulbs was heavily mulched, and this mulch was left on in the spring. Still no fire disease was discovered on the plants and no evidence of the organism noted except in the case of skinned bulbs, upon which a few of the black sclerotia, which carry the organism over the dormant season, were found. This was the report in spite of the fact that a test was made with over 100 bulbs in bad condition on account of being skinned and bruised. These bulbs were produced at Bellingham and showed considerable fire disease.

DISEASES OF HYACINTHS.

The hyacinth is troubled with enemies more than the other two groups. The most serious trouble thus far has been the yellows, or "new disease," which has been investigated by Wakker[1] and by Smith.[2] This is detected in the bulb by a softening when far advanced. If a bit of the nose of the bulb is cut off, the diseased condition can be detected by the yellow discoloration appearing in rings, segments of rings, or dots. It is a common practice with bulb growers to "nose" all bulbs planted, in order to detect this disease. Our experience, however, shows that this practice leads to very serious complications unless done with extreme care, so that we are now decidedly of the opinion that it may be a wiser plan to cull carefully without "nosing" and depend on taking out diseased plants during the growing season. At that time the disease can be detected by the water-soaked appearance of the plant and in advanced stages by the wilting down of the leaves. Great care should be exercised to cull out plants in the incipient stages of the disease in order to prevent the spread of infection. The Dutch grower uses for the removal of diseased plants a strong galvanized-iron tube 6 inches in diameter and 2 feet long, like a giant cookie cutter. This is inserted in the ground and a plug of earth, including the diseased bulb, is removed and destroyed. This "snotkoker" we have not thus far been able to use, on account of the greater density of our soils.

Stock as free as possible from this disease should be secured for propagation. It is not impossible, however, to clean up slightly infected stocks, provided the effort is intelligent and persistent. This cleaning has actually been accomplished upon our grounds by the process of culling and selection previously mentioned. Every step in the process of hyacinth culture should be carefully guarded, in order to prevent the spread of this disease.

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[1] Wakker, J. H. Contributions à la pathologie végétale. *In* Arch. Néerland. Sci. Exact. et Nat. t. 23, p. 18–20. 1889.

[2] Smith, Erwin F. Wakker's hyacinth germ. U. S. Dept. Agr., Div. Veg. Phys. and Path., Bul. 26, 45 pages, 6 fig., 1 col. pl. 1901.

Another trouble to be feared on hyacinths is the "old disease" of the Netherlands. This also exhibits itself in rings, but they are dark. This also should be guarded against and culled out, as in the case of the yellows. In the growing plant this disease shows itself in the leaves in much the same way, but the water-soaked area is much more easily distinguished by the darker discoloration of the tissues of the leaf. This disease is caused by the eelworm (*Tylenchus dipsaci*). The organism can be seen on an examination under a low-power microscope of a portion of the tissue from the edge of the infestation macerated in water. The eelworm seen with the naked eye, commonly present, is a very different thing, which should not cause alarm.

THE MOSAIC DISEASE.

All the classes of bulbs treated in this bulletin are more or less affected with the mosaic disease, which in all cases reduces the vitality and stature of the plants. The Sir Watkin and Princeps Maximus narcissi and, of course, the broken tulips exhibit the condition most. Our work has demonstrated that this disease can be reduced if not quite gotten out of narcissi by selection. It is well known that it does not appear in seedlings. This is the "gray disease" of the Netherlands. It is carefully culled out of both narcissi and hyacinths, but when it comes to tulips the case is very different. Here the breaking, as it is called, gives a very spectacular and commonly pleasing effect in the flowers that is greatly admired. Consequently, nearly as long lists of broken tulips as of breeders have been segregated and established as commercial varieties. Their use and study are more extensive in the British Isles than elsewhere.

It would probably be much wiser for the commercial grower in this country not to attempt to plant these broken tulips, for a time at least, or if he grows them to do so at a safe distance from the breeders, which will always be the main stocks, for it has been repeatedly shown that this diseased condition is communicable. This mosaic affection should be looked upon just as much as a disease in tulips as it is in other well-known plants. There exists abundant evidence of the communicability of this disease, and there are some suggestions that the aphis may be the main carrier.

THE BEST VARIETIES TO PLANT.

While there might be substantial agreement among growers as to the best varieties of hyacinths to plant, fewer would agree on lists of narcissi, and it would be difficult to find two who would agree on the same list of tulips. Any recommendations, therefore, of tulip or narcissus varieties are subject to all sorts of revisions, but may be useful to those who have had little or no experience with the

wealth of decorative material in these groups. In the preparation of any list availability must be one of the first requisites. Here, again, one is very likely to encounter great differences of opinion and conditions while we continue to be dependent, as we are, upon foreign importations. The importing florist and seedsman have to depend upon the foreign grower. The purchaser of bulbs in this country depends upon his florist. The varieties which can be found on the markets are often limited and vary from year to year. There are, however, certain standard varieties in the three groups which are nearly always obtainable, such as the now widely used and easily propagated Marie, Roi des Belges, Grand Maitre, and L'Innocence in hyacinths; Emperor, Empress, Golden Spur, and Sir Watkin in narcissi; and Chrysolora, Keizerskroon, Couleur Cardinal, Cottage Maid, Clara Butt, Faust, and Pride of Haarlem in tulips. These are all produced by the hundreds of thousands each year and the private individual will always find satisfaction in using them. The commercial grower, of course, will give his lists the most careful study and consider the demands of the trade which he intends to supply. It is more than likely that American production will for a long time limit itself to varieties for which there is a very great demand and will grow much fewer varieties than are now offered for sale in Dutch and British catalogues.

Already this specialization is evident. Although the largest producer of Dutch bulbs at the present time is handling a very long list in each group, this is confessedly experimental, the avowed intention being finally to sift out the less desirable and concentrate upon the standard varieties. Another large firm grows 60 to 80 varieties of narcissi, but their production in large quantity is confined to not more than a dozen. Another firm grows mainly two forcing varieties of narcissi and a few other forcing bulbous stocks, specializing as it were upon forcing bulbs.

VARIETIES OF NARCISSI.

Most of the lists of narcissus of any pretension are now compiled in accordance with the recommendations of the committee of the Royal Horticultural Society of England,[1] which arranged a classification into 11 divisions, the last of which is a catchall, made up mainly of botanical species. The following list, arranged according to this catalogue, is made up of varieties which stand a good chance of doing well under varying conditions. Another useful grouping not recognized by the committee of the Royal Horticultural Society but commonly found in catalogues is the Poetaz section, made up of hybrids

[1] Royal Horticultural Society. Classified List of Daffodil Names, 1914. 73 p. [London, 1914.]

between the Tazetta and Poeticus groups. These varieties are among the most desirable of the bunch-flowered forms and are represented in this list by the last three in Division VIII.

The varieties in this list are dual-purpose ones in largest part, i. e., adapted to both indoor and outdoor culture. The exceptions are the first three named under the Tazettas. These are adapted to out-of-door use in the warmer sections of the country.

FIG. 21.—The Golden Spur narcissus, a most popular trumpet daffodil.

FIG. 22.—The Glory of Leyden narcissus (trumpet daffodil).

Telamonius Plenus (Double Van Sion) will usually not give satisfaction after the first year either out of doors or indoors. In all situations where it has been tried, except on the immediate coast north of San Francisco, the North Atlantic coast, and high, cool situations elsewhere, it turns green after the first year.

I. *Long trumpets* (as long as perianth segments).—Daffodils.

(*a*) Trumpets and perianth segments the same or different shades of yellow.

Golden Spur (fig. 21).	Emperor.
Henry Irving.	Glory of Leyden (fig. 22).
King Alfred.	Obvallaris.

(*b*) Trumpets and perianth white.

Madame de Graaff.	Albicans.
W. P. Milner.	Loveliness.

(*c*) Perianth white; trumpets some shade of yellow. (Bicolor.)

Madame Plemp.	Weardale Perfection.
Empress (fig. 23).	Glory of Noordwijk.
Victoria.	Mrs. Morland Crosfield.

II. *Incomparabilis.*—Large chalice-cupped daffodils; trumpet one-third to one-half the length of the perianth segments.

Sir Watkin (fig. 24).
Lucifer.
Autocrat.
Great Warley.
Gloria Mundi.
Gwyther.

III. *Barrii.*—Small chalice-cupped daffodils; trumpet less than one-third the length of the perianth segments.

Barrii Conspicuus (fig. 25).
Firebrand.
Seagull.
Toreador.
Mohican.

IV. *Leedsii.*—Like Incomparabilis and Barrii; but the flowers white or yellow tinted.

Fairy Queen.
Maria Magdalene de Graaff.
White Lady.
Mrs. Langtry (fig. 26).

FIG. 23.—The Empress narcissus. Experimental planting at Bellingham, Wash.

V. *Triandrus hybrids.*—Cyclamen-flowered daffodils.

Triandrus Albus (Angels' Tears).
Queen of Spain.
Agnes Harvey.

VI. *Cyclamineus hybrids.*—Yellow cyclamen-flowered daffodils.

Cyclamineus and its hybrids.

VII. *Jonquilla hybrids.*[1]—The hybrids of Narcissus Jonquilla—Jonquils.

Buttercup.
Jonquilla.
Odorous Campernelle.
Rugulosus Maximus.

VIII. *Tazetta and its hybrids.*—Bunch-flowered narcissi.

Paperwhite Grandiflora.
Chinese sacred lily.
Double Roman.
Elvira (figs. 27 and 28).
Klondike.
Jaune a' Merveille.

[1] These are the only true jonquils. [2] Commonly called "narcissi."

FIG. 24.—The Sir Watkin narcissus—the giant Welsh daffodil (Incomparabilis group).

FIG. 25.—Narcissus Barrii Conspicuus (Barrii group).

FIG. 26.—The Mrs. Langtry narcissus (Leedsii group).

FIG. 27.—The Elvira narcissus (Poetaz group).

IX. *Poeticus varieties.*[1]—Snow-white perianth and variously colored short trumpet.

Praecox Grandiflora. Minerva.
Cassandra. The Bride.
Ornatus (fig. 29).

X. *Double varieties.*

Trumpets.—Telamonius Plenus (Double Van Sion) (fig. 30).
Incomparabilis.—Argent, Sulphur Phoenix (Codlins and Cream). Primrose Phoenix.

FIG. 28.—A block of 25,000 Elvira narcissi. Experimental planting at Bellingham, Wash.

VARIETIES OF TULIPS.

The classification of the tulip is purely artificial and a complicated subject, most seriously attempted in 1917 by a committee of the Royal Horticultural Society of England.[2]

Tulips are first divided into early, late, or May flowering, which need no definition, and species which are found native. The earlies are divided into the Duc van Tholl, which are very early dwarfs, the singles, and the doubles.

The lates are divided (1) into the Cottage subsection, which is a catchall that is not definable except that its members do not belong in the other groups; (2) breeders which are self-colors; (3) broken or mosaic tulips, parrots which have laciniate floral segments; and (4) double late tulips.

[1] Commonly called "narcissi."
[2] Report of the Tulip Nomenclature Committee, Royal Hort. Soc., London. 1917.

The largest and most popular after the single earlies are the breeders.[1] The flowers are self-colored except the base. They are divided into Dutch, English, and Darwins—the Dutch with a cup-shaped flower, the English with a hemispherical flower, and the Darwins with a rectangular-based flower. The Dutch and English breeders are again subdivided into three divisions: Roses, which are pink to red in color, the ground or tissue of the petals below the epidermis being white; Bybloemen, which are purple to violet and also have a white ground; and Bizarres, which have shades of scarlet to bronze with a yellow ground.

FIG. 29.—Narcissus Poeticus Ornatus (Poeticus group).

As stated elsewhere, the broken tulips are subdivided the same as the breeders from which they are derived. Their irregular distribution of the epidermal colors superimposed upon white or yellow grounds gives very brilliant and attractive effects. None of the varieties, however, are as vigorous as the breeders from which they are derived.

FIG. 30.—The Double Van Sion narcissus. Experimental planting at Bellingham, Wash.

SECTION I.

Early flowering. (In full flower before the end of April.)

A. *Duc van Tholl.*—The earliest of all. Single dwarf, rarely exceeding 6 inches in height. May be had in a variety of colors and commonly listed as Duc van Tholl red, Duc van Tholl white, etc.

[1] The single earlies are also breeders.

B. *Single flowered.*—Early but larger than the previous group and better for dual purposes.

White.—White Hawk, Pottebakker white.

Blush-pink.—La Reine and La Reine Maxima, Cottage Maid.

Red-yellow.—Grand Duc (Keizerskroon) Hector, Duchesse de Parma.

Orange.—Fred Moore and Thomas Moore.

Scarlet and orange-scarlet.—Prince of Austria, Couleur Cardinal, Artus, Vermilion Brilliant.

Yellow.—Mon Tresor (fig. 31), Yellow Prince, Chrysolora.

C. *Double flowered.*

White.—Schoonoord, La Candeur.

Scarlet.—Vuurbaak, Imperator Rubrorum.

Orange and red.—El Toreador, Prince of Orange.

Red (edge yellow).—Tournesol.

FIG. 31.—The Mon Tresor tulip, a variety of the "Single Early" group. Experimental planting at Bellingham, Wash.

SECTION II.

Late or May flowering.

A. *Cottage varieties.*—A catchall for a miscellaneous lot of breeder varieties not belonging to the other groups of this section.

Several colors.—Ingelscombe, Gesneriana, Fulgens, Didieri, and Elegans varieties.

White.—La Candeur (Parisian White), Royal White.

Yellow.—Glare of the Garden, Golden Eagle, Parisian Yellow, Retroflexa, Yellow Perfection, Bouton d'Or, Golden Crown, Retroflexa Grandiflora.

Rosy white.—The Fawn, Isabella.

Scarlet.—La Merveille, Scarlet Mammoth.

Primrose.—Vitellina.

B. *Breeders.*—The flowers are of one color except the base.

(1) *Dutch breeders.*—Flower oval or cupped, brown, purple, or red, but sometimes bronze. Base white or yellow, but usually stained blue or green to blue-black.

(*a*) Roses (pink to red).—Charles Dickens, Crimson Beauty, Annie McGregor.

(*b*) Bybloemen (purple to violet).—Cardinal Manning, Godet Parfait, Roi de Siam, Louis XIV.

(*c*) Bizarres (scarlet, bronze, or brown).—Panorama, Louis XIV, James Watt, Turenne, Dom Pedro.

FIG. 32.—The Sieraad van Flora tulip of the "Darwin" group, and other varieties. Experimental planting at Bellingham, Wash.

(2) *English breeders.*—Flower cup shaped, forming one-half of a hollow ball when expanded, the base being white or yellow.

(*a*) Roses (rose shades with white base).—Annie McGregor, Mabel, Mrs. Barlow.

(*b*) Bybloemen (purple shades with white base).—Adonis, Elizabeth Peck, Talisman.

(*c*) Bizarres (brown shades with yellow base).—Sir Joseph Paxton, Goldfinder, Sulphur, Samuel Barlow.

(3) *Darwins.*—Lower portion of flowers rectangular; shades of purple, red, or white, never yellow or brown. Base black-blue or white or any combination.

Pale rosy.—Flamingo, White Queen, Margaret, Mrs. Cleveland.

B. *Breeders*—Continued.

(3) *Darwins*—Continued.

Rose.—Anton Roozen, Baronne de la Tonnaye, Clara Butt, Loveliness, Psyche, Massachusetts, Sieraad van Flora. (Fig. 32.)

Red.—Europe, Feu Brilliant, Harry Veitch, King George V, Farncombe Sanders, Pride of Haarlem, Prof. Francis Darwin, Prof. Rauwenhoff, Whistler.

Mauve, light lilac.—Bleu Amiable, Dream, Euterpe, Lantern, Remembrance, Rev. H. Ewbank.

Purple, dark blue.—Bleu Celeste, Frans Hals, Marconi, Mrs. Potter Palmer, Viking.

Maroon.—Faust, Black Knight, Zulu, Fra Angelico, Othello, La Tulipe Noire.

C. *Broken tulips.*—The mosaic tulips in which color is in irregular stripes and accentuated streaks in the flowers and foliage.[1]

(1) *Broken Dutch.*

(*a*) Roses (rose or cherry markings on white ground).—Admiral van Kingsberger, Comte de Vergennes, Henry VIII, Perle Brilliante.

(*b*) Bybloemen (violet or purple markings on white ground).—Dainty Maid, Imperatrice de Maroc, May Blossom.

(*c*) Bizarres (brown, red, or purple markings on yellow ground).—Chebourg, Miss Doris Diggle, Trafalgar.

(2) *Broken English.*

(*a*) Roses (rose markings on white ground).—Annie McGregor, Mabel Aglaia.

(*b*) Bybloemen (purple markings on white ground).—Adonis, Duchess of Sutherland.

(*c*) Bizarres (brown or black markings on yellow ground).—Samuel Barlow, Sir Joseph Paxton, Dr. Hardy, George Hayard, Lord Stanley.

(3) *Rembrandt* (Broken Darwins).

(*a*) Roses (rose markings on white ground).—Red Prince, Semele, Victor Hugo, Galatea.

(*b*) Bybloemen (purple markings on white ground).—François d'Amboise, Pericles, Wedding Veil, Remembrance, Gretchen.

(4) *Broken Cottage.*

(*a*) Roses (rose markings on white ground).—Striped Beauty, Zommerschoon.

(*b*) Bybloemen (purple markings on white ground).—Twilight, Union Jack.

(*c*) Bizarres (brown, red, or purple markings on yellow ground).—Chameleon, Gala Beauty, Scotia.

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[1] A similar condition is found in narcissi and hyacinths, when it is known in the Netherlands as the "gray disease." The subdivisions of the May-flowering groups are duplicated in this group. In other words, any of the self-colored tulips may become broken and are ever after weaker in constitution and require careful handling to keep up to the necessary vigor. They are consequently little cultivated, with the exception of the Rembrandts, which, owing to the excessive vigor of the Darwins, of which they are broken forms, are still vigorous enough to endure and give satisfaction. Aside from the Rembrandts, these are seldom seen in this country. In the list of varieties enumerated, therefore, little more has been done than to copy the leading varieties as given by the English Tulip Nomenclature Committee.

D. *Parrots.* Segments of flowers cut or laciniated.
Sensation, Markgraaf, Lutea Major, Admiral de Constantinople.
E. *Doubles.* Blue Flag, Mariage de ma Fille, Orange Brilliant, Yellow Rose.

SECTION III.

Species of tulips growing in the state of nature.
Clusiana, Greigii, Hageri, Praestans, Sylvestris.

VARIETIES OF HYACINTHS.

Hyacinths are listed by color in singles and doubles, the singles being much the more popular. They are offered for sale in several classes, such as miniatures and first and second sizes, which are approximately 18 and 16 cm. bulbs, respectively. Besides these, there is commonly a miniature size (about a 13-cm. bulb) offered for bedding and growing in pots.

The Dutch-Roman hyacinth is grown the last year in the south of France, where the season is earlier and the bulbs are consequently capable of being forced into blossom correspondingly earlier than Holland-grown stocks of the same varieties.

The "Dutch prepared" hyacinth is a recent invention, being the ordinary Dutch varieties grown in the Netherlands, but dug early and incubated in artificial heat for the purpose of accelerating the development of the flower buds during the dormant period. These are also capable of being forced into flower earlier. These bulbs are often "soft," due to withering under the artificial treatment, and their appearance is consequently not necessarily an index to their performance.

These early forcing varieties, especially the "Dutch prepared," often are not successful in this country, mainly owing to improper conditions for rooting. Our atmospheric and soil temperatures in late August and early September are too high to root them properly except in cool cellars.

The Roman hyacinth is also offered along with the Dutch varieties. It is early, more graceful than the stiff Dutch varieties, and is grown in southern France. It is adapted only to indoor culture except in the South, while the Dutch varieties are hardy.

The following list, considered from the standpoint of availability and performance, is suggestive. The varieties are those commonly offered for sale and, of course, the leading and most popular sorts.

Single red and rose.
Gertrude, Gigantea, Roi des Belges, General de Wet, Lady Derby.
Single white.
L'Innocence, Mr. Plimsoll, Baroness van Thuyll, Madam van der Hoop.
Single blue.
Captain Boyton, Grand Maitre, Queen of the Blues, Marie, Schotel.

Single yellow.
Yellow Hammer, King of the Yellows.
Double red and rose.
Bouquet Royal, President Roosevelt, Prince of Orange.
Double white and blush.
Bouquet Royal, Isabella, Prince of Waterloo.
Double blue.
Bloksberg, General Köhler, Van Speyk.
Double yellow.
Goethe, William III.

BULB LITERATURE.

The literature of bulbs is exceedingly varied and exhaustive, but commonly not available to the average reader. American writings are fragmentary, although they also are quite voluminous. In spite of these facts, anyone with a little effort may get in touch with abundant sources of information on the subject. There are four main sources to consult—

(1) Florist, horticultural, and agricultural papers. These are replete with writings on various phases of the subject, and every issue of many of them carries advertisements of bulb literature.

(2) Of bulb books there are many. They are exhaustive and comprehensive and written in English. A few are American, but most of them are of British origin.

(3) Florist catalogues contain succinct and pointed information regarding the handling of bulbs for decoration. Some of the larger houses issue separate leaflets and pamphlets on methods of culture. These may be had for the asking when purchasing bulbs.

(4) The florists have the columns of their trade papers, as stated on a previous page. Here are to be found the crystallized personal experiences of experts in the commercial production of florist materials.

DEFINITIONS.

Much of the information in bulb literature and even in popular catalogues is in language quite strange to the uninitiated. Like every other specialized line of endeavor, the bulb business possesses a considerable language of its own. The following definitions will assist in a better understanding of some of these expressions.

Barrii.—A group of narcissi having small chalice-cupped coronas or trumpets.

Bed.—A Dutch bulb bed is a meter wide, of any convenient length, but usually about 10 meters (about 33 feet) long.

Bicolor.—A trumpet narcissus with yellow trumpets and white perianth segments.

Bizarres.—Tulips of various shades of scarlet to brown in the breeder and broken sections, but, unlike the bybloemens, they have a yellow ground.

Blower.—A machine or contrivance for removing the loose hulls and other light material from bulbs.

Breeders.—Tulips with self-colored flowers. The color of the base of the flower is not taken into account.

Broken tulips.—Tulips in which the coloring matter is unequally distributed in both flowers and foliage.

Bulb.—A fleshy underground bud with thick succulent scales. It is an entire plant condensed into a gigantic bud.

Bulb house.—The storehouse in which bulbs are kept and handled between the time of digging and planting.

Bybloemen.—Tulips of various shades of purple to violet in the breeder and broken sections. The ground color of the petal (the color of the tissue between the epidermal layers) is white.

Centimeter.—One 1/100th of a meter, or about two-fifths of an inch.

Cleaning.—Separation of bulbs from the clumps in which they grew and the removal of dirt and chaff from them.

Corona.—The crown cup or tube of the narcissus flower.

Culling.—Removal of undesirable bulbs.

Curing.—The treatment of bulbs in storage.

Cutting.—Removing tulip and hyacinth flowers from the beds.

Daffodils.—The largest section of the genus Narcissus. It includes in common parlance all but the rush-leaved forms, or jonquils.

Darwins.—For the most part a robust May-flowering group of tulips with flowers of a rectangular form at the base.

Double Earlies.—Double-flowered early tulip varieties.

Dropper.—A stemlike growth frequent in many classes of bulbs. It grows downward some distance from the parent bulb and gives rise at its extremity to a new deeper set bulb.

Dutch bulbs.—Tulips, narcissi, and hyacinths, besides a score of other bulbs and roots which in the Netherlands are propagated for sale. They are often called Holland bulbs.

Dutch-Roman.—Hyacinths of the Dutch varieties grown the last year in the south of France.

Dutch prepared.—Dutch hyacinths dug early and subjected to artificial heat to hasten the development of the flower spike.

Fire.—An abbreviated term for the fire disease of tulips caused by the fungus *Botrytis parasitica.*

Gray disease.—The mosaic of hyacinths and narcissus.

Hyacinth.—A low, herbaceous perennial of the lily family, usually with a large spike of bell-shaped flowers terminating a short scape and a coated bulb with outer coats papery, similar to those of the narcissus or the onion.

Hyacinth, Roman.—A species distinct from the Dutch hyacinth. It is more graceful than the latter and not adapted to out-of-door culture except in the South.

Hyacinth, Dutch.—The common hyacinth.

Incomparabilis.—A group of narcissi having large chalice-cupped coronas.

Increase.—The propagated stock of bulbs of any one period.

Jonquils.—A small group of the genus Narcissus with rushlike leaves. The terms narcissus, daffodil, and jonquil are used as common names very loosely and with a great deal of confusion. Often people use the name daffodil to designate all the single-flowered forms except the rush-leaved ones and the Poeticus section. The rush-leaved forms are called jonquils and the bunch-flowered and Poeticus groups narcissi.

Leedsii.—A group of narcissi like the Incomparabilis and Barrii sections, but the flowers are white or only slightly yellowish tinted.

Marker.—A machine with a revolving drum used to lay off the boundaries and the rows of a bulb bed.

Meter.—A unit of metric measurement, 39.37 inches.

Mosaic.—A term used to designate any irregular distribution of coloring matter in leaves and floral parts of the plants.

Narcissus.—A low, herbaceous, perennial plant belonging to the amaryllis family, having narrow radical leaves, flowers with a corona or trumpet, and the outer coats dry and papery but not continuous, like that of the tulip.

Narcissus fly.—Two species of flies are conspicuous in narcissus bulbs. The large *Merodon equestris* is commonly known as the greater narcissus fly and the small *Eumerus strigatus* as the lesser narcissus fly. The first is parasitic and the second is considered saprophytic.

New disease.—The yellow disease of hyacinths caused by *Bacillus hyacinthi.*

Old disease.—A nematode disease, especially of hyacinths.

Packing material.—Buckwheat hulls, rice chaff, sawdust, etc., used in packing bulbs.

Parasite.—An organism which is able to attack and destroy live and healthy plants.

Parrots.—Tulips with cut or laciniate floral parts.

Path.—A narrow passageway of 12 to 16 inches between successive beds of bulbs.

Perianth.—The outer floral envelope of the flower.

Plat.—As here used, a land bordered by a walk, road, or ditch, or all of them combined, its width being the length of the bulb beds.

Poets' Narcissus.—A group of the genus Narcissus having a pure white perianth and variously colored short crowns.

Propagation.—The increasing of stocks of plants by any process.

Rembrandts.—Broken Darwin tulips.

Roguing.—The process of digging out and getting rid of undesirable plants or plants out of place.

Roses.—Tulips of various shades of pink to rose in the breeder and broken sections. They have a white ground (tissue between the epidermal layers of the petals).

Row.—A row in a Dutch bulb bed is a meter in length and extends across the bed. The rows are usually about 6 inches apart.

Saprophyte.—An organism which lives only on the dead tissues.

Scooping.—A method of propagating hyacinths consisting of the scooping out of the basal plate (stem) and exposing the scale edges to callousing and subsequent budding, which results in the production of bulblets.

Scoring.—A method of propagating hyacinths in which the basal plate is hacked by three or four cuts through its diameter, for the same purpose as scooping.

Shaker.—A machine designed to remove mechanically the loose dirt from bulbs.

Sieves.—Sieves are of two kinds. The shaker has a sieve through which the dirt passes and this is sometimes referred to as a sieve. The nesting circular parchment sizers are also often referred to as sieves.

Single earlies.—Single-flowered early tulip varieties.

Sizers.—These are machines employed for separating bulbs into different sizes. The separation is accomplished by means of an oscillating screen, preferably of parchment, perforated to allow the passage of objects of a definite circumference measured in centimeters (cm.). A large oscillating plane made up in

sections is employed in the machine (Vlinder) most used in the Netherlands. Simpler machines are a common circular nesting sieve, which may be used singly, or when nested three of four together, in a specially constructed hand shaker, when several sizes of bulbs may be taken out at once.

Tazetta.—A bunch-flowered narcissus; also the specific name of the original bunch-flowered species.

Trays.—Flat receptacles for storing bulbs in the bulb house.

Trumpet.—The crown, or corona, of the narcissus.

Tulip.—A low, herbaceous, perennial plant of the lily family with a scapelike, single-flowered stem from a tunicated bulb, the outer layer of which is continuous and ruptures before growth starts.

Vlinder.—See under Sizers.

Walk.—The vacant space left as a passageway between the bulb plats, which many include ditching space.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 798

Contribution from the Bureau of Soils
MILTON WHITNEY, Chief

Washington, D. C. ▼ October 20, 1919

A SURVEY OF THE FERTILIZER INDUSTRY.

Prepared under the direction of Wm. Wallace Mein, Assistant to the Secretary in Charge of Fertilizer Control.

By E. A. Goldenweiser, *Statistician.*

CONTENTS.

INTRODUCTION.

The Fertilizer Control was created under authority of the food control act as a war emergency measure in the Department of Agriculture. Soon after its establishment this office undertook a survey of the fertilizer industry in order to determine the materials used, the products, and the stocks of ingredients and of mixed goods on hand. In view of a serious shortage of several of the materials that enter into the manufacture of fertilizer, it was deemed important to ascertain what the requirements of the industry were, in order to stimulate production of the scarce ingredients, and, if it became necessary, to apportion the available supply of scarce materials on an equitable basis. A series of questionnaires was sent out by the office of Fertilizer Control. The information collected is for the calendar years 1917 and 1918. In the case of fertilizer manufacturers a schedule was first obtained for 1917 and the first six months of 1918, and then another schedule was sent out to cover the last six months of 1918. Data on phosphate rock were obtained for 1918, information for 1917 having been collected by the Bureau of Soils. A potash schedule was sent out later in the year, and called for reports for

1917, for the first nine months of 1918, and for estimates for the remaining three months of 1918. A schedule for tankage producers was sent out toward the end of the year, and called for reports for the two calendar years 1917 and 1918. Data are thus available for a study of the fertilizer industry during two years, both of which were war years. No comparison with prewar years can be made, for lack of data, but a future survey of the industry in years after war activities have ceased will afford interesting comparisons.

MATERIALS USED IN MIXED FERTILIZERS.

Table I shows the amount of materials of different kinds used in the manufacture of mixed fertilizers during the years 1917 and 1918.

TABLE I.—*Materials used in producing fertilizer as reported by fertilizer manufacturers.*

[2,000-pound tons.]

Kind of material.	1917	1918	Kind of material.	1917	1918
Agricultural lime	32,602	40,252	Nitrogenous materials—Con.		
Agricultural salt	2,474	2,650	Ammonium phosphate	20,237	7,096
Acid phosphate	3,746,693	[1] 3,554,000	Tankage:		
Potash materials:			Animal tankage (high grade)	185,491	134,446
Potassium sulphate	13,420	16,808	Animal tankage (low grade)	108,775	82,209
Potassium muriate	12,124	19,189	Garbage tankage	123,835	96,142
Potassium nitrate	14,478	17,286	Tankage (n. o. s.)	5,994	4,770
Potassium carbonate	7,656	5,706	Dried blood	37,189	25,799
Kainite	2,175	368	Cottonseed meal	306,399	273,876
Manure salts	1,684	194	Fish scrap (dried)	28,769	28,813
Nebraska potash	7,201	18,815	Fish scrap (acidulated)	17,234	24,215
Cement dust	6,489	6,301	Castor bean pomace	19,948	36,481
Furnace dust	8,499	12,105	Hair	9,254	7,179
Roasted alunite	667	1,999	Hoof meal	6,340	5,681
Kelp (dried)	3,064	4,777	Horns	200	74
Kelp (ash)	2,929	3,722	Hide scrap	218	921
Kelp (char)	16	348	Leather scrap or meal	18,078	13,892
Tobacco waste	37,218	30,816	Leather (acidulated)	75	.....
Wood ash and other plant ash	6,523	7,458	Wool waste	1,135	1,002
Manure ash	2,197	2,768	Tartar pomace	2,709	2,893
Feldspar	601	134	Peat (dried)	742	1,892
Sugar factory waste	5,071	5,250	Natural guano	67,715	52,549
Other potash materials	33,863	34,898	Base goods	518,378	502,132
Nitrogenous materials:			Other nitrogenous materials	39,162	29,259
Sodium nitrate	285,983	234,794	Filler	161,932	216,764
Ammonium sulphate	125,283	103,356	Other materials (n. o. s.)	6,986	11,294
Cyanamid	37,230	6,099			
Nitrate of lime	33	595			

[1] Partly estimated.

The figures for 1918 are not altogether comparable with those for 1917, as 55 companies included in the tabulation for 1917 and for the first six months of 1918 failed to make reports for the last six months of 1918. In the case of acid phosphate an estimate has been made to cover the companies for which reports were not received for July to December, 1918.

The principal kinds of material reported are acid phosphate (the chief carrier of phosphoric acid), potash-bearing materials, and nitrogenous materials. A certain quantity of agricultural lime, agricultural salt, and filler was also reported, and a comparatively small

quantity of other materials which it was not possible to classify. It is probable that the figures for filler are not complete, as the schedule did not specifically ask for it, and many of the firms doubtless neglected to report the quantities used, and the same is likely to be true of the agricultural salt and possibly of the lime. In connection with the reported quantity of filler, it should be kept in mind that the filler used in the preparation of mixed fertilizer is only a small part of the inert matter in the product. In the manufacture of mixed fertilizer, filler is used largely for the purpose of obtaining the desired grade or composition in the mixed goods. A concrete example may help to make this proposition clear. If it is desired to make a mixture containing 2 per cent of ammonia, 8 per cent of phosphoric acid and 2 per cent of potash (the well-known grade, 2–8–2) and the materials at hand are cottonseed meal, containing 7 per cent of ammonia, acid phosphate, containiug 16 per cent of phosphoric acid, and Nebraska potash, containing 28 per cent of potash, the method of making up the mixture will be as follows: 2 per cent of a 2,000-pound ton is 40 pounds; in order to obtain 40 pounds of ammonia from 7 per cent cottonseed meal it will be necessary to use 571 pounds of cottonseed meal. The amount of phosphoric acid desired is 8 per cent of a ton or, in fertilizer parlance, 8 units, or 160 pounds. To obtain 160 pounds from a 16 per cent acid phosphate will require 1,000 pounds of acid phosphate. The amount of potash called for is 40 pounds and to obtain that from a 28 per cent material, 143 pounds will be required. The total amount of materials used, therefore, will be 571 plus 1,000 plus 143, or 1,714 pounds. To this are added 286 pounds of filler in order to make up the ton.

It will be seen from the foregoing statement that filler has not only a legitimate but a necessary use in the preparation of mixed fertilizer under the existing methods of manufacture. While it is likely that in the 5 million tons of fertilizer produced during 1918 more than 217,000 tons of filler were used, the filler constituted only a small proportion of the inert matter in the mixture. Thus, in the example given, the 2,000-pound ton contained 286 pounds of filler, while the total of inert matter was as follows: Of the 571 pounds of cottonseed meal, 531 pounds were inert; of the 1,000 pounds of acid phosphate, 840 pounds were inert; and of the 143 pounds of Nebraska potash, 103 pounds were inert; so that the total inert matter in the plant food bearing materials was 1,474 pounds; and the ton of fertilizer consisted of 240 pounds of plant food, 1,474 pounds of inert matter in the plant food bearing materials, and 286 pounds of filler.

The fact that from three-fourths to seven-eighths of the mixed fertilizer sold to farmers consists of inert matter which does not contribute to the fertility of the soil, but on which freight must be

paid and which must be ground and bagged and transported, is one of the fundamentals in the fertilizer industry. If a means were devised by which farmers could buy practically undiluted plant food and make up their own mixtures, an enormous saving would be effected, and any method that would decrease the amount of inert matter carried in fertilizers would be of great benefit to the agriculture of the country. The quantity of filler used is only a minor phase of this problem, but perhaps the part of it which is most easily susceptible of improvement while the present general methods prevail in the industry.

SULPHURIC ACID AND ACID PHOSPHATE.

Some of the fertilizer manufacturers produce their own sulphuric acid, while others buy sulphuric acid. Of the 425 companies for which this office secured returns, 68 were producers of sulphuric acid. These firms used the quantities of pyrites and sulphur shown in Table II in the production of sulphuric acid for the periods to which the schedule refers:

TABLE II.—*Materials used in the manufacture of sulphuric acid.*

[2,000-pound tons.]

Material.	1917.	January to June inclusive, 1918.
Pyrites	585,317	244,154
Sulphur	104,556	85,625

The proportion of sulphur used during the first six months of 1918 was much greater than the corresponding proportion during 1917. In pre-war times Spanish pyrites was practically the only source of sulphuric acid, as pure sulphur was too expensive to be used in the manufacture of the acid, but owing to lack of shipping facilities, caused by the war, it became very difficult to obtain pyrites from Spain; on the other hand, the price of sulphuric acid advanced decidedly as a result of the demand for the acid by manufacturers of munitions, so that it became profitable to make the acid out of pure sulphur. Domestic and Canadian sources of pyrites were utilized, but they were not sufficient to supply the demand. In addition to sulphur and pyrites, a certain amount of nitrate of soda is used in the manufacture of sulphuric acid, but the schedules did not call for the uses to which nitrate of soda was put, and there is no way of determining how much was used in connection with the acid chambers and how much went into mixed fertilizers. Beginning with July, 1918, the Nitrate Committee of the

War Industries Board did not permit fertilizer manufacturers to have any nitrate of soda for mixing, and allowed them only enough for the manufacture of sulphuric acid, estimating roughly that their requirements of nitrate of soda amounted to about 1 per cent of their total sulphuric acid production.

Most of the large fertilizer companies make their own acid phosphate. Such firms are known as wet mixers, of whom 104 reported. Table III shows the quantity of material used in the manufacture of acid phosphate during 1917 and during the first six months of 1918.

TABLE III.—*Material used in the production of acid phosphate.*

[2,000 pound tons.]

Material.	1917.	January to June inclusive, 1918.
Phosphate rock	2,206,523	1,172,124
Steamed ground bone	71,925	33,196
Raw ground bone	31,657	22,667
Bone black	986	600
Basic slag	128	77
Other phosphatic materials	484	326
Sulphuric acid	2,135,113	1,068,464

The companies used more than 2,200,000 tons of phosphate rock in the manufacture of acid phosphate during 1917, as compared with only 72,000 tons of steamed ground bone, and 32,000 tons of raw ground bone with small quantities of other phosphatic materials. The quantity of sulphuric acid used is approximately the same as that of the phosphorus-bearing materials.

The production of phosphate rock was conducted by a number of the fertilizer companies and by other producers, mostly in Florida. Many of the big fertilizer companies are interested in the phosphate fields and are producing their own rock. The total production of phosphate rock amounted to 2,696,000 short tons, in 1918, as compared with 2,588,000 short tons in 1917. The 1918 total is analyzed in Table IV.

TABLE IV.—*Phosphate rock produced in 1918.*

[2,000-pound tons.]

Kind of rock.	Short tons.	Kind of rock.	Short tons.
Total	2,695,543	Tennessee:	
		Brown rock	377,511
Florida:		Blue rock	52,777
Hard rock	42,840	South Carolina	51,387
Soft phosphate	17,736	Utah	1,532
Land pebble	2,141,950	Idaho	3,211
		Kentucky	6,599

The greatest production was of Florida land pebble (2,142,000 tons), which alone comprised about four-fifths of the entire output. Tennessee brown rock, of which 378,000 tons were mined, is next in

importance. The production of but two of the other kinds amounted to 50,000 tons.

Table V shows the quantity of phosphate rock marketed in the United States during the six months from January to June, 1918, distinguishing between the amount that was used in the manufacture of acid phosphate and the amount that was sold directly to farmers for application to the soil. It also shows the quantity exported and the stocks on hand at three given dates.

TABLE V.—*Phosphate rock marketed January–June, 1918, and stocks on hand Jan. 1, 1917 and 1918, and June 30, 1918.*

[2,000-pound tons.]

Kind of rock.	Quantity marketed in United States January–June, 1918.		Quantity exported January–June, 1918.	Stocks on hand.		
	To acid phosphate manufacturers.	To farmers for direct application.		Jan. 1, 1917.	Jan. 1, 1918.	June 30, 1918.
Total	805,735	65,225	27,664	713,290	974,564	944,665
Florida:						
Hard rock			2,732	174,530	220,824	228,162
Soft phosphate	58	6,559	1,002	326	370	170
Land pebble	706,935	45,203	21,385	499,407	748,243	708,780
Tennessee:						
Brown rock	93,854	11,364	2,545	39,020	5,121	7,547
Blue rock	587	2,100				
South Carolina	22			7	6	6
Utah	1,061					
Idaho	3,211					
Kentucky	7					

The great mass of the rock marketed during the period under discussion was in the form of Florida land pebble, of which 774,000 tons were marketed during the first six months of 1918, and the next most important quantity was of Tennessee brown rock. It should be noted that most of the rock is sold to manufacturers of acid phosphate, and that only small quantities, amounting to about 7 per cent of the total marketed in the United States, are sold to farmers for direct application to the soil. The exports for the six months of 1918 were very small, owing to the difficulty of obtaining cargo space. A notable fact is that the accumulation of phosphate rock in the hands of the mining companies is large. Very little hard rock was produced during the first six months of 1918, and the small quantity produced was exported, but a very considerable amount of that rock, more than 200,000 tons, was in stock. The stocks of the Florida land pebble rock were large and increased from 499,000 tons at the beginning of 1917 to 748,000 tons at the beginning of 1918, but declined somewhat during the six months period, January–June, 1918.

SOURCES OF NITROGENOUS MATERIALS.

Table VI and a graph (fig. 1) show the sources of ammonia used in mixed fertilizers. The table shows the total amount of each material used, as reported by the fertilizer manufacturers, the average ammonia content, the total quantity of ammonia in each material, and the proportion of the total ammonia derived from each source.

TABLE VI.—*Sources of ammonia in mixed fertilizer.*

Material.	Average per cent of ammonia.	Quantity of material used (2,000-pound tons).		Units of ammonia in materials used (unit =20 pounds).		Percentage of ammonia from each source.	
		1917	1918	1917	1918	1917	1918
All sources				18,620,200	15,039,300	100	100
Sodium nitrate	18.8	285,983	234,794	5,376,500	4,414,100	28.9	29.4
Ammonium sulphate	24.3	125,283	103,356	3,044,400	2,511,600	16.3	16.7
Cyanamid	15.6	37,230	6,099	580,800	95,100	3.1	.6
Nitrate of lime	15.6	33	595	500	9,300		.1
Ammonium phosphate	13.0	20,237	7,098	263,100	92,300	1.4	.6
Tankage:							
Animal (high grade)	11.0	185,491	134,446	2,040,400	1,478,900	11.0	9.8
Animal (low grade)	7.0	108,775	82,209	761,400	575,500	4.1	3.8
Garbage	3.3	123,835	96,142	408,700	317,300	2.2	2.1
Tankage (n. o. s.)	6.3	5,994	4,770	37,800	30,100	.2	.2
Dried blood	13.8	37,189	25,799	513,200	356,000	2.8	2.4
Cottonseed meal	8.4	306,399	273,876	2,573,800	2,300,600	13.8	15.3
Fish scrap (dried)	9.0	28,769	28,813	258,900	259,300	1.4	1.7
Fish scrap (acidulated)	6.0	17,234	24,215	103,400	145,300	.6	1.0
Castor bean pomace	6.6	19,948	36,481	131,700	240,800	.7	1.6
Hair	18.0	9,254	7,179	166,600	129,200	.9	.9
Hoof meal	15.0	6,340	5,681	95,100	85,200	.5	.6
Horns	15.0	200	74	3,000	1,100		
Hide scrap	12.0	218	921	2,600	11,100		.1
Acidulated leather	9.0	75		700			
Leather scrap or meal	13.0	18,078	13,892	235,000	180,600	1.3	1.2
Wool waste	7.0	1,135	1,002	7,900	7,000		
Tartar pomace	.9	2,709	2,893	2,400	2,600		
Peat (dried)	1.5	742	1,892	1,100	2,800		
Natural guano	7.8	67,715	52,549	528,200	409,900	2.8	2.7
Base goods	2.4	518,378	502,132	1,244,100	1,205,100	6.7	8.0
Other nitrogenous materials	6.1	39,162	29,259	238,900	178,500	1.3	1.2

The total amount of ammonia used during 1917 was more than 18,600,000 units of 20 pounds, and the total amount used during 1918 exceeded 15,000,000 units.

The principal source of ammonia during both years for which data were obtained was sodium nitrate, nearly 30 per cent of the ammonia being derived from that one source.

The second source in importance was ammonium sulphate, from which about one-sixth of the ammonia was derived.

Among the organic sources of ammonia, tankage and cottonseed meal are by far the most important. The proportion of ammonia derived from animal tankage of high and of low grade was less in 1918 than in 1917, owing, probably, to the great demand for tankage as feed. The proportion derived from cottonseed meal increased from 13.8 per cent in 1917 to 15.3 per cent in 1918.

Nearly four-fifths of the ammonia in fertilizers is thus derived from the two great mineral sources, sodium nitrate and ammonium sulphate, together with the two principal organic sources, tankage and cottonseed meal.

The only other important source of ammonia reported is "base goods," a designation which indicates that the original source is not given, base goods being a name by which the companies call preliminary mixtures which are stored in large bins against the time when orders need to be filled and the base goods are mixed with other ingredients to obtain a desired grade of goods.

Other sources of ammonia worth mentioning are cyanamid, which yielded 581,000 units of ammonia in 1917 but only 95,000 units in 1918, owing to the fact that this material was requisitioned by the Ordnance Department; and dried blood, which accounted for 2.8 per cent and 2.4 per cent, respectively, during 1917 and 1918.

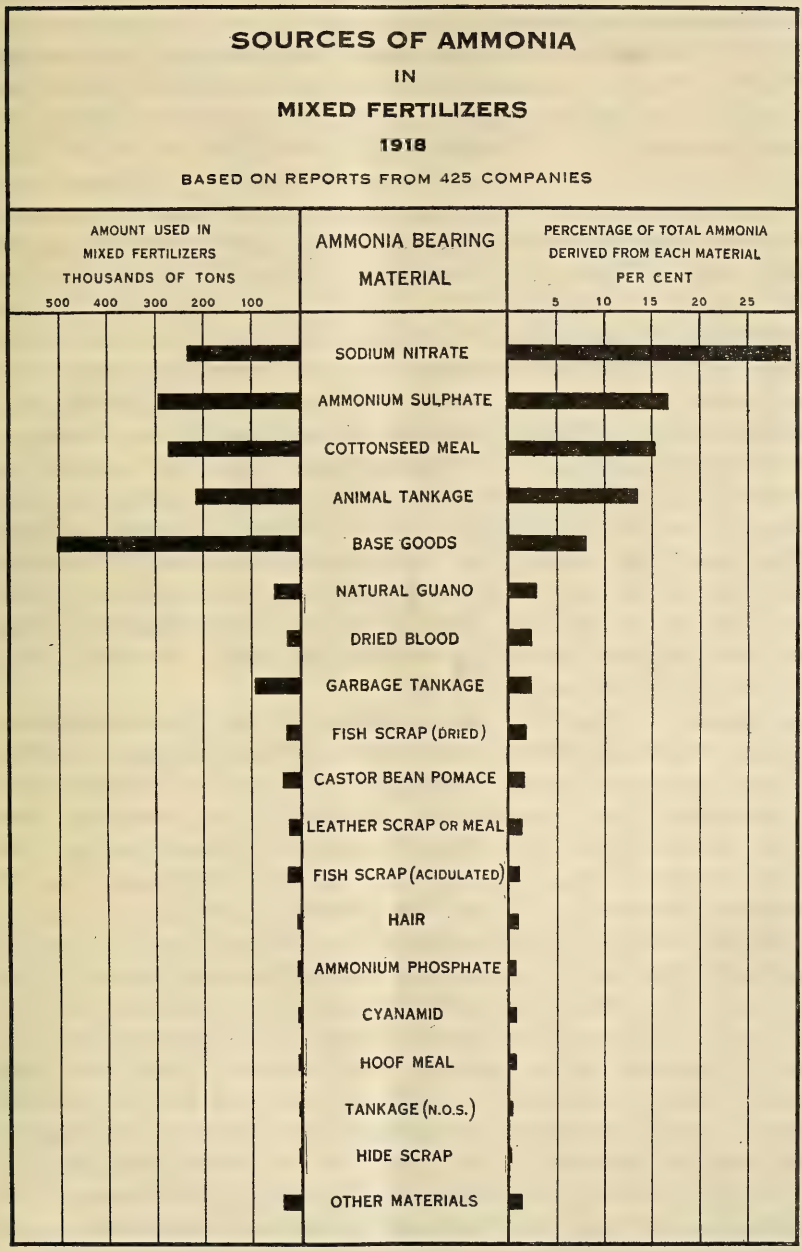
Tankage.—A special inquiry about the amount of tankage produced was sent out by the office of Fertilizer Control, and returns from 503 packers and renderers were received. Table VII shows the total quantity of tankage and allied materials produced during 1917 and 1918, and the quantity marketed in 1918 to be used as fertilizer, to be used for feed, and for other purposes.

TABLE VII.—*Tankage and allied products produced in 1917 and 1918 and marketed in 1918.*

Kind of material.	Production, 503 firms reporting (2,000-pound tons).		Quantity marketed in 1918, 386 firms reporting (2,000-pound tons).				Percentage marketed, 1918.		
	1917	1918	Total.	As fertilizer.	As feed.	For other purposes.	As fertilizer.	As feed.	For other purposes.
Animal tankage (high grade)	157,300	185,839	182,320	103,703	78,187	430	56.9	42.9	0.2
Animal tankage (low grade)	59,604	64,614	62,805	56,239	5,213	1,354	89.5	8.3	2.2
Concentrated tankage	24,674	25,490	26,098	16,540	9,481	77	63.4	36.3	.3
Garbage tankage	36,997	34,718	28,598	28,598	.....	.....	100	.....	.....
Tankage (n. o. s.)	7,750	10,004	3,732	3,122	58	552	83.7	1.6	14.7
Dried blood	32,007	35,463	32,578	26,918	5,671	.....	83.6	1.5	14.9
Raw bones	27,981	33,644	26,451	22,607	3,281	862	82.6	17.4	.....
Dried bones	24,348	21,475	20,158	20,093	5	60	85.5	12.3	3.2
Hair	5,617	8,754	4,638	1,941	.....	2,698	41.8	.....	58.2
Hoofs and horns	6,715	4,671	4,008	3,539	386	83	88.3	9.6	2.1
Meat scrap	3,265	3,233	3,561	.....	3,549	11	.....	99.7	.3

The 503 firms for which returns were received produced 157,000 tons of high-grade tankage in 1917 and 186,000 tons in 1918. The quantity of low-grade tankage was about one-third of the amount of high-grade tankage, and in addition there were about 25,000 tons of concentrated tankage in each of the two years 1917 and 1918, and about 35,000 tons of garbage tankage, with a certain amount of tankage the character and quality of which were not

FIGURE 1.


SOURCES OF AMMONIA
IN
MIXED FERTILIZERS
1918
BASED ON REPORTS FROM 425 COMPANIES
AMOUNT USED IN MIXED FERTILIZERS THOUSANDS OF TONS
500 400 300 200 100
AMMONIA BEARING MATERIAL
PERCENTAGE OF TOTAL AMMONIA DERIVED FROM EACH MATERIAL PER CENT
5 10 15 20 25
SODIUM NITRATE
AMMONIUM SULPHATE
COTTONSEED MEAL
ANIMAL TANKAGE
BASE GOODS
NATURAL GUANO
DRIED BLOOD
GARBAGE TANKAGE
FISH SCRAP (DRIED)
CASTOR BEAN POMACE
LEATHER SCRAP OR MEAL
FISH SCRAP (ACIDULATED)
HAIR
AMMONIUM PHOSPHATE
CYANAMID
HOOF MEAL
TANKAGE (N.O.S.)
HIDE SCRAP
OTHER MATERIALS

indicated. Dried blood and raw and dried bones were the other important items. The amount of hair, hoof, and horns, and meat scrap was not very large.

Of the 503 firms from which reports were received, 386 reported sufficient data on the purposes for which their products were used to make a tabulation possible. While less than four-fifths of the firms reported that information, the quantities for which they reported were a very large proportion of the total. In some cases the amount marketed was somewhat greater than the amount produced, which probably means that an additional amount was sold from stock. About 57 per cent of the high-grade animal tankage was marketed as fertilizer and about 43 per cent as feed. If these percentages are representative, they indicate one of the reasons that animal ammoniates were difficult to secure during the year 1918. Of the low-grade tankage, however, 89.5 per cent was marketed as fertilizer, while of the concentrated tankage nearly two-thirds was so marketed, and of the garbage tankage the entire amount was disposed of as fertilizer. In the case of dried blood, more than four-fifths was marketed as fertilizer, and of the raw bones even a higher proportion, while of the dried bones nearly the entire amount was used as fertilizer, and of the hoofs and horns seven-eighths. About two-fifths of the hair was used as fertilizer, the remainder being used for purposes other than fertilizer or feed. The meat scrap was practically all used for feed.

A special investigation was conducted by the Food Administration, in cooperation with the Office of Fertilizer Control, covering all the reduction plants, municipal or otherwise. According to the returns of that investigation, which were very complete, these plants produced, in 1917, 168,000 tons of garbage tankage, and in 1918, 159,000 tons. The recovery per ton of garbage was 262 pounds of tankage in 1917 and 286 pounds in 1918.

Cottonseed meal.—In connection with cottonseed meal, an inquiry was made from all the mills that manufacture cottonseed oil and meal as to the amount produced during the fiscal year July 1, 1917, to June 30, 1918, and the amount disposed of for different purposes and in different ways. Returns were received from 506 mills having a total production of cottonseed meal and cake of 1,600,000 tons, or about four-fifths of the total production, which was for this period, as reported by the Census Bureau, about 2,000,000 tons.

Table VIII shows that of the total quantity of cottonseed meal produced about 4 per cent was used by the mills themselves in the manufacture of fertilizer. About 400,000 tons were sold direct to farmers, while the remainder was shipped to other points. Of the quantity sold to farmers, nearly equal proportions were used as feed and as fertilizer, while a very large proportion of the material that

was shipped to other points was used as feed. This may be due to the fact that in order to be able to pay freight on cottonseed meal it is necessary to utilize it in the most efficient way. It is also probably true that the meal shipped away was of a higher grade than that used in the immediate vicinity of the oil mill.

TABLE VIII.—*Production and disposal of cottonseed meal and cake, by States, July 1, 1917, to June 30, 1918.*

AMOUNTS IN 2,000-POUND TONS.

State.	Number of mills reporting.	Total tons of cottonseed meal and cake produced.	Quantity used by mills in the manufacture of fertilizer.	Quantity sold to farmers to be used as—		Quantity shipped to other points to be used as—		Undistributed.
				Feed.	Fertilizer.	Feed.	Fertilizer.	
Total for 16 States	506	1,616,617	62,656	186,952	200,905	756,581	243,625	165,898
Alabama	41	78,352	4,738	8,107	6,210	26,645	12,424	20,228
Arizona	3	6,597	.....	2,406	.....	4,191	.....	.....
Arkansas	32	137,633	3,226	14,510	3,305	104,690	8,614	3,288
California	1	7,327	.....	.....	.....	7,327	.....	.....
Florida	3	6,692	.....	160	440	4,025	2,067	.....
Georgia	107	346,603	23,691	29,879	52,781	114,786	71,638	53,828
Illinois	1	3,781	.....	300	.....	3,481	.....	.....
Kentucky	1	5,173	.....	1,000	.....	3,773	400	.....
Louisiana	25	140,434	427	9,490	8,224	80,671	41,622	.....
Mississippi	48	214,715	6,917	16,718	9,210	140,023	18,841	23,006
Missouri	3	20,130	.....	1,080	.....	19,050	.....	.....
North Carolina	57	129,466	13,049	13,024	42,251	11,985	40,683	8,474
Oklahoma	48	141,282	1,098	43,910	2,080	94,194	.....	.....
South Carolina	75	161,804	9,409	21,748	71,230	15,565	43,852	.....
Tennessee	20	105,368	.....	2,540	4,378	62,199	3,484	32,676
Texas	41	111,260	101	22,080	796	63,976	.....	24,307

PERCENTAGES.

State.	Used by mills in the manufacture of fertilizer.	Sold to farmers to be used as—		Shipped to other points to be used as—		Total percentage used as—	
		Feed.	Fertilizer.	Feed.	Fertilizer.	Feed.	Fertilizer.
Total for 16 States	4.3	12.9	13.8	52.2	16.8	65.1	34.9
Alabama	8.2	13.9	10.7	45.8	21.4	59.7	40.3
Arizona	.....	36.5	.....	63.5	.....	100.0	.....
Arkansas	2.4	10.8	2.5	77.9	6.4	88.7	11.3
California	.....	.....	.....	100.0	.....	100.0	.....
Florida	.....	2.4	6.6	60.1	30.9	62.5	37.5
Georgia	8.1	10.2	18.0	39.2	24.5	49.4	50.6
Illinois	.....	7.9	.....	92.1	.....	100.0	.....
Kentucky	.....	19.3	.....	73.0	7.7	92.3	7.7
Louisiana	.3	6.8	5.9	57.4	29.6	64.2	35.8
Mississippi	3.6	8.7	4.8	73.1	9.8	81.8	18.2
Missouri	.....	5.4	.....	94.6	.....	100.0	.....
North Carolina	10.8	10.8	34.9	9.9	33.6	20.7	79.3
Oklahoma	.8	31.0	1.5	66.7	.....	97.7	2.3
South Carolina	5.8	13.5	44.0	9.6	27.1	23.1	76.9
Tennessee	.....	3.5	6.0	85.7	4.8	89.2	10.8
Texas	.1	25.4	.9	73.6	.....	99.0	1.0

In the aggregate, two-thirds of the cottonseed meal was used as feed and one-third as fertilizer. There is a considerable variation in this respect between the different States. In Arizona, California, Illinois, and Missouri all of the cottonseed meal was reported as being used for feed, and in Oklahoma, Texas, Tennessee, Kentucky, and

Arkansas more than seven-eighths of the cottonseed meal was so used. On the other hand, in the Eastern States a greater proportion was used for fertilizer. The highest proportion used for that purpose was 79.3 per cent in North Carolina, with South Carolina only slightly below that percentage, 76.9 per cent. In Georgia about one-half of the cottonseed meal was used for fertilizer and in Alabama 40 per cent. These are the States that depend on the liberal use of fertilizer for the continuation of their chief industry, which is cotton growing. The farmers in these States find it good economy to return the cottonseed meal to the soil so as to enable it to produce the maximum amount of new cotton plants. It is a characteristic of the cotton plant that comparatively little plant food is removed from the soil provided the seed is returned to the ground.

POTASH-BEARING MATERIALS.

A special schedule was sent to all the producers of potash. The returns on this schedule refer to the years 1917 and 1918. The 1918 returns are based on actual operations for the first nine months and on estimates for the remaining three months. Table IX shows the quantity of potash produced from each of the principal sources and the proportion derived from each source.

TABLE IX.—*Potash produced from the different sources during 1917 and 1918.*

Source.	Quantity of K_2O produced (2,000-pound tons).		Percentage of total K_2O produced from each source.	
	1917	1918	1917	1918
Total from all sources	32,258	53,538	100	100
Mineral sources:				
Total	25,450	43,820	78.9	81.8
Brines	21,445	38,658	66.5	72.2
Flue dust from blast furnaces	245	303	.8	.6
Cement dust	1,454	2,015	4.5	3.7
Alunite	2,306	2,557	7.1	4.8
Slate	.....	176	.....	.3
Greensand	.....	111	.....	.2
Organic sources:				
Total	6,808	9,718	21.1	18.2
Kelp	3,372	5,092	10.5	9.5
Tobacco waste	2,006	1,861	6.2	3.5
Beet-sugar factory waste	1,134	2,119	3.5	4.0
Wood ashes	296	646	.9	1.2

The total potash produced during 1918, as reported to this office, including estimates for the last three months, was 53,500 tons, a figure which exceeds by about 1,400 tons the more recent estimates made by the Geological Survey. This difference is probably due in part to the fact that actual production during October, November, and December, 1918, was not as great as had been expected by the producers. The returns, moreover, fail to include potash extracted

from molasses-distillery waste, of which 2,846 tons were produced in 1917 and 3,322 tons in 1918, according to the Geological Survey estimates. When this quantity is added to the above total, the production appears to have been about 57,000 tons. It seems likely, therefore, that the total production for the year fell not less than 3,000 tons, and probably over 5,000 tons, below the estimate of 60,000 tons current during the year. It will be seen that more than four-fifths of the potash is derived from mineral sources and that among these sources lake brines alone account for considerably over two-thirds of the potash. The next most important source in 1918 was kelp, the giant seaweed of the Pacific coast, from which over 5,000 tons of K_2O was derived during the year. Some of the other important sources are alunite, beet-sugar factory waste, cement dust, and tobacco waste.

With the signing of the armistice and the cessation of hostilities the question arose whether the American potash industry which was created by the war emergency will be able to survive under normal conditions. In prewar years the United States consumed about 250,000 tons of potash a year, practically all of which was imported from Germany. When the German supply was cut off in 1914, the United States turned its attention to domestic production, which has increased from year to year, reaching during 1918 the figure of 53,000 tons, or about one-fifth of the annual prewar consumption. Some crops probably have suffered during this period from a lack of potash, but the main needs of the country were supplied in spite of this temporary decline in the consumption of potash. The price of potash rose from between 75 cents and $1 a unit to between $4 and $5 a unit, and even more, and with this great increase in price the domestic manufacturers entered the field of production. Whether they will be able permanently to compete with European potash is an open question.

PRODUCTION OF MIXED FERTILIZERS.

Table X shows the production of mixed fertilizer during 1917 and 1918. It also shows the quantity of acid phosphate and other ingredients sold as such.

TABLE X.—*Production of mixed fertilizer and fertilizer materials sold as such reported by fertilizer manufacturers.*

[2,000-pound tons.]

Kind of material.	1917	1918	Kind of material.	1917	1918
Mixed fertilizer produced	4,442,528	4,957,799	Tankage	8,114	37,827
Materials sold as such:			Blood	3,126	2,304
Acid phosphate	2,097,232	2,024,574	Fish scrap	1,749	1,889
Phosphate rock	393	542	Cottonseed meal	6,682	7,987
Bones:			Natural guano	1,152	6,266
Raw bones	10,023	7,532	Nitrate of soda	7,241	11,334
Steamed bones	698	3,249	Ammonium sulphate	531	2,334
Raw bone meal	11,379	15,707	Cyanamid	117	4
Steamed bone meal	683	1,336			

Of the 2,000,000 tons of acid phosphate reported sold as such, a considerable quantity was sold to dry mixers who used it in preparing the final product. The quantity of acid phosphate used by dry mixers in 1917 was 494,261 tons, leaving about 1,500,000 tons of acid phosphate sold for direct application to the soil. The quantity of mixed fertilizer produced was 4,443,000 tons in 1917 and 4,958,000 tons during 1918. Certain quantities of bone, tankage, blood, fish scrap, and cottonseed meal were sold in their original state; also some nitrate of soda, but beginning with July, 1918, practically no nitrate of soda was sold as such.

Brands.—Each fertilizer manufacturer was asked to give the quantity of each grade of fertilizer he produced during the periods referred to in the schedule; also the names of such fertilizers and the crops for which they were recommended. Table XI gives the quantities of each of the principal grades produced in 1917.

TABLE XI.—*Distribution of fertilizer produced in 1917, by grades.*

Grade.			Quantity produced (2,000-pound tons) in 1917.	Percentage of total production.	Cumulative percentage.	Grade.			Quantity produced (2,000-pound tons) in 1917.	Percentage of total production.	Cumulative percentage.
Total goods for which grade was reported.			3,179,135	100	.....	Total goods for which grade was reported.			3,179,135	100	.....
NH_3	P_2O_5	K_2O				NH_3	P_2O_5	K_2O			
2	10	0	340,664	10.71	10.71	2	9	2	13,356	.42	73.17
3	9	0	193,468	6.08	16.79	1	12	1	12,640	.39	73.56
2	12	0	164,830	5.18	21.97	4	8	3	12,549	.39	73.95
2	8	2	163,756	5.15	27.12	1	7	1	11,605	.36	74.31
4	8	0	137,737	4.33	31.45	3	9	1	11,381	.35	74.66
3	8	0	126,192	3.96	35.41	3½	9	0	11,199	.35	75.01
2	10	2	91,618	2.88	38.29	3	11	0	11,100	.34	75.35
4	10	0	79,749	2.50	40.79	1	8	2	10,956	.34	75.69
5	10	0	74,289	2.33	43.12	3	12	0	10,938	.34	76.03
1	10	0	72,879	2.29	45.41	1	9	0	10,511	.33	76.36
3	8	2	66,830	2.10	47.51	3	5	0	10,419	.32	76.63
3	10	0	54,585	1.71	49.22	1½	9	1	10,340	.32	77.00
1	8	1	54,331	1.70	50.92	1.65	10	0	10,116	.31	77.31
3	8	3	47,546	1.49	52.41	4	8	1	9,956	.31	77.62
2	9	1	43,977	1.38	53.79	½	11	1	9,894	.31	77.93
5	8	0	39,042	1.22	55.01	1	11	0	9,217	.28	78.21
7	8	0	34,307	1.07	56.08	1½	10	0	9,207	.28	78.49
2½	8	1	34,277	1.07	57.15	1	2	1½	9,198	.28	78.77
1	12	0	30,964	.97	58.12	2	11	1	8,814	.27	79.04
2	11	0	30,491	.95	59.07	½	11	½	8,560	.26	79.30
2½	8	0	30,491	.95	60.02	4	12	3	8,500	.26	79.56
4	6	0	27,957	.87	60.89	½	9	1	8,336	.26	79,82
0	16	3	27,769	.87	61.76	7	9	0	8,296	.26	80.08
½	12	0	27,499	.86	62.62	4	12	0	7,960	.25	80.33
3	8	1	26,992	.84	63.46	½	10	0	7,952	.25	80.58
1½	10	0	24,352	.76	64.22	4	7½	0	7,604	.23	80.81
4	8	2	24,137	.75	64.97	3½	10	0	7,412	.23	81.04
4	8	4	21,955	.69	65.66	2½	27	0	7,377	.23	81.27
1	10	1	21,915	.68	66.34	0	10	2	7,273	.22	81.49
2	8	0	21,796	.68	67.02	1¾	7	0	7,162	.22	81.71
1	8	0	20,390	.64	67.66	1.65	11	0	6,931	.21	81.92
2	10	1	19,755	.62	68.28	1	8	3	6,798	.21	82.13
2¾	9	2	19,222	.60	68.88	3	9	2	6,614	.20	82.33
1	9	1	16,960	.53	69.41	5	8	3	6,389	.20	82.53
2¾	8½	1¾	15,906	.50	69.91	4	9	0	6,327	.19	82.72
2	9	0	15,897	.50	70.41	2½	10	0	6,107	.19	82.91
6	7	0	15,816	.49	70.90	½	10	1	5,997	.18	83.09
3	24	0	15,637	.49	71.39	6	10	0	5,888	.18	83.27
1	3	1	15,000	.47	71.86	2	11½	0	5,689	.17	83.44
2	8	1	14,719	.46	72.32	2	8	3	5,559	.17	83.61
5	7	0	13,949	.43	72.75	1	10	½	5,484	.17	83.77


LOCATION
OF
FERTILIZER PLANTS
1918
EACH DOT REPRESENTS ONE PLANT
CIRCLES INDICATE THE LOCATION OF MORE THAN ONE PLANT IN A CITY OR TOWN

TABLE XI.—*Distribution of fertilizer produced in 1917, by grades*—Continued.

Grade.			Quantity produced (2,000-pound tons) in 1917.	Percentage of total production.	Cumulative percentage.	Grade.			Quantity produced (2,000-pound tons) in 1917.	Percentage of total production.	Cumulative percentage.
Total goods for which grade was reported.			3,179,135.	100	.....	Total goods for which grade was reported.			3,179,135	100	.....
NH_3	P_2O_5	K_2O				NH_3	P_2O_5	K_2O			
½	8	1	5,423	.17	83.95	10.09	9.05	0	2,009	.06	90.70
½	8	0	5,419	.17	84.12	0	12	2	2,005	.06	90.76
5	6	0	5,298	.16	84.28	4	10	3	2,003	.06	90.82
6	12	0	5,082	.16	84.43	4	5	0	1,989	.06	90.88
2	12	¼	5,015	.15	84.58	2	10	½	1,959	.06	90.94
1	10	5	4,790	.15	84.73	2½	8	3	1,945	.06	91.00
½	8	½	4,761	14	84.87	1½	30	0	1,917	.06	91.06
3	9	3	4,717	.14	85.01	1	11	½	1,913	.06	91.12
2	7	2	4,711	.14	85.15	1	10.18	1	1,891	.05	91.17
4½	9	5	4,685	.14	85.29	7	7	1	1,838	.05	91.22
6	8	0	4,629	.14	85.43	4½	20	0	1,823	.05	91.27
1	13	20	4,493	.14	85.57	1	15	1	1,815	.05	91.32
2	9	3	4,522	.14	85.71	½	8	¼	1,812	.05	91.37
2½	12	0	4,391	.13	85.84	6½	30	0	1,775	.05	91.42
½	12	½	4,357	.13	85.97	0	12	1	1,764	.05	91.47
½	13	1	4,294	.13	86.10	5	9	0	1,751	.05	91.52
4	7	1	4,254	.13	86.23	4	7	0	1,704	.05	91.57
2	27	0	4,214	.13	86.36	1¼	13	0	1,682	.05	91.62
4	7	3	4,130	.12	86.48	2	11	½	1,661	.05	91.67
3	10	1	4,049	.12	86.60	½	50	½	1,655	.05	91.72
1½	19	0	3,979	.12	86.72	5	8	4	1,637	.05	91.77
1.65	12	0	3,930	.12	86.84	1¾	9	0	1,620	.05	91.82
2	8½	1	3,776	.11	86.95	¾	15	0	1,617	.05	91.87
3	5½	0	3,704	.11	87.06	½	14	0	1,588	.04	91.91
2	10	3	3,662	.11	87.17	1¼	12	0	1,585	.04	91.95
½	15	0	3,655	.11	87.28	7	8	1	1,578	.04	91.99
5	8	2	3,569	.11	87.39	4½	10	0	1,564	.04	92.03
1	14	0	3,496	.10	87.49	4	7	½	1,562	.04	92.07
5	7	3	3,377	.10	87.59	2	9½	1½	1,554	.04	92.11
12	20	0	3,345	.10	87.69	1.65	10½	½	1,553	.04	92.15
5	7	1	3,343	.10	87.79	1¾	7	1	1,544	.04	92.19
1¼	8	0	3,317	.10	87.89	6¼	7	3	1,543	.04	92.23
1	8	½	3,275	.10	87.99	5.5	5	0	1,524	.04	92.27
1	13	0	3,242	.10	88.09	2	14	0	1,512	.04	92.31
7	7	0	3,172	.09	88.18	1.65	12	0	1,506	.04	92.35
4	11	0	3,074	.09	88.27	8	8½	0	1,462	.04	92.39
2¼	28	0	3,047	.09	88.36	3½	20	0	1,453	.04	92.43
1	23	0	3,002	.09	88.45	5	7	½	1,449	.04	92.47
1½	12	0	2,942	.09	88.54	2	20	0	1,443	.04	92.51
5	8	1	2,913	.09	88.63	2	8½	1½	1,441	.04	92.55
4	6.07	5	2,850	.08	88.71	2	6	3	1,416	.04	92.59
1	20	0	2,815	.08	88.79	½	8	2	1,395	.04	92.63
1½	10	1	2,771	.08	88.87	3	10	12	1,392	.04	92.67
3	8	½	2,762	.08	88.95	1¾	9.55	0	1,382	.04	92.71
2.9	8	2	2,583	.08	89.03	4½	24	0	1,378	.04	92.75
7	7	3	2,517	.07	89.10	½	13	½	1,373	.04	92.79
4	9	1	2,508	.07	89.17	4	9	2	1,348	.04	92.83
5	6	¾	2,507	.07	89.24	1	29	0	1,322	.04	92.87
5	7	5	2,499	.07	89.31	4½	10½	0	1,310	.04	92.91
1	9	2	2,485	.07	89.38	5¼	7	0	1,296	.04	92.95
2	8	4	2,469	.07	89.43	1	16	3	1,239	.03	92.98
2½	8	2	2,432	.07	89.52	4	7½	1	1,239	.03	93.01
3	9	½	2,386	.07	89.59	7	9	1	1,235	.03	93.04
4	6	3	2,382	.07	89.66	3	12	1	1,212	.03	93.07
1	¼	10	2,366	.07	89.73	1.21	9	1	1,204	.03	93.10
6	7	2	2,361	.07	89.80	5	6	3	1,197	.03	93.13
4½	8	1	2,310	.07	89.87	½	10	¼	1,176	.03	93.16
4	6	1	2,306	.07	89.94	8	8	0	1,175	.03	93.19
½	9	½	2,299	.07	90.01	2¼	13	0	1,150	.03	93.22
6	6	0	2,289	.07	90.08	1	12	3	1,096	.03	93.25
4	10	1	2,267	.07	90.15	6.07	10	13	1,068	.03	93.28
½	1	10	2,248	.07	90.22	4	12	13	1,054	.03	93.31
1½	9	0	2,187	.06	90.28	2½	10	1	1,052	.03	93.34
4½	23	0	2,119	.06	90.34	1¼	10	1	1,045	.03	93.37
4	6	2	2,118	.06	90.40	5	5	0	1,027	.03	93.40
2	12	1	2,104	.06	90.46	9	2.17	0	1,000	.03	93.43
2	16	0	2,104	.06	90.52	1.22	10	0	1,000	.03	93.46
2½	9	0	2,031	.06	90.58	All other grades (724 grades).....			132,125	4.15	.....
2½	11	0	2,013	.06	90.64						

The reports by grades were satisfactory for a total of over three million tons of mixed fertilizer, or about two-thirds of the total reported as manufactured during 1917. These figures may be considered sufficiently complete to be indicative of the general situation. Table XI shows that 218 grades were manufactured in quantities of 1,000 tons or more. These 218 grades comprised over 95 per cent of the total mixed fertilizer produced, while the remaining 4 and a fraction per cent of the mixed fertilizer was distributed in small quantities among 724 grades. Thirteen grades carried about one-half of the fertilizer business, the leading ones being 2–10–0, 3–9–0, 2–12–0, 2–8–2, 4–8–0, 3–8–0, 2–10–2, 4–10–0, 5–10–0, 1–10–0, 3–8–2, 3–10–0, and 1–8–1. It will be noted that only four of this list contain any potash, namely, grades, 2–8–2, 2–10–2, 3–8–2, and 1–8–1, which had only 1 or 2 units of potash. This condition was primarily due to the scarcity and high price of potash.

The most significant fact brought out by the tabulation is that the number of grades in the market could be reduced to less than one-fourth of the present number without cutting down the production by more than 4 per cent of its present quantity.

There is a strong feeling in the industry that it would be helpful if the number of grades manufactured were restricted in some way. A trade agreement along that line would be advantageous, not only to the fertilizer manufacturers, but also to the farmers. A large number of different grades of fertilizer are produced which differ so slightly from each other that no perceptible difference in their effect on plants can be expected.

STOCKS.

The schedule sent to fertilizer manufacturers included a question referring to stocks of different materials on hand on January 1, 1917, January 1, 1918, and June 30, 1918. This information was asked for when the end of the war was not in sight and when it was proposed to have a periodical inquiry every three months or every six months. The main purpose of the inquiry was to ascertain whether the stocks of any ingredient were getting low, in order to take measure to avoid the shortage, and, on the other hand, to see whether any materials were being unduly hoarded by some firms at the expense of other firms. Since there is no immediate prospect of continuing the periodical reports, the information on stocks loses much of its value. It is, however, appended here (Table XII) because it may be of some interest to the users of this bulletin.

The stocks on hand on June 30, 1918, were much lower in nearly every case than they were on January 1 of either of the years 1917 and 1918, a natural result of the fact that most of the production and sales of fertilizer take place in the first half of the year and that,


COMMERCIAL FERTILIZER
PRODUCTION DURING YEAR ENDING JUNE 30
1918
CIRCLES VARY IN SIZE WITH PRODUCTION
QUANTITIES ARE SHOWN IN THOUSANDS OF TONS

therefore, the stocks on June 30 are at a low ebb. One of the items worth noting in connection with the stocks is the increase in the stock of potash in 1918 as compared with 1917. The production of potash in this country had increased decidedly and the stocks on hand were much larger than a year earlier. The stocks of sodium nitrate were greater in January, 1918, than in January, 1917, but the stocks of ammonium sulphate had declined and the stock of cyanamid was very low owing to the fact that cyanamid was practically all requisitioned by the Ordnance Department. The supply of tankage and of dried blood was lower in 1918 than in 1917, owing to the great demand for these materials as feed. On the other hand, cottonseed meal was represented by a larger stock in 1918 than in 1917.

TABLE XII.—*Stocks of mixed fertilizer and of fertilizer materials reported by fertilizer manufacturers.*

[2,000-pound tons.]

Kind of material.	Jan. 1, 1917.	Jan. 1, 1918.	June 30, 1918.	Kind of material.	Jan. 1, 1917.	Jan. 1, 1918.	June 30, 1918.
Mixed fertilizer	654,217	644,453	270,327	Nitrogenous materials:			
Pyrites	238,085	233,251	203,070	Sodium nitrate	55,782	104,818	47,488
Sulphuric acid	79,566	97,323	99,712	Ammonium sulphate	24,591	22,880	32,786
Sulphur	11,357	47,393	45,147	Cyanamid	19,272	5,730	1,525
Agricultural lime	6,834	8,086	6,336	Nitrate of lime	129	348	4
Agricultural salt	1,260	411	679	Ammonium phosphate	1,911	1,507	2,606
Phosphatic materials:				Tankage—			
Acid phosphate	1,207,171	1,434,900	742,929	Animal tankage (high grade)	67,954	43,993	44,090
Phosphate rock	230,905	315,175	271,012	Animal tankage (low grade)	35,131	26,650	18,540
Steamed ground bone	15,047	18,970	24,260	Garbage tankage	21,051	18,407	18,380
Raw bone	20,001	17,625	16,172	Tankage (n. o. s.)	2,212	1,343	664
Basic slag	673	261	235	Dried blood	17,499	15,353	10,821
Bone black	393	134	163	Cottonseed meal	62,446	107,266	60,093
Bone ash	43	33	33	Fish scrap (dried)	22,456	16,649	6,517
Other phosphatic materials	21	153	109	Fish scrap (acidulated)	10,753	7,857	5,949
Potash materials:				Castor bean pomace	5,671	12,095	4,471
Potassium sulphate	3,785	9,734	5,668	Hair	1,782	3,395	2,635
Potassium muriate	5,026	11,274	8,767	Hoof meal	1,470	2,466	2,042
Potassium nitrate	2,900	5,794	1,022	Hoofs and horns	342	442	335
Potassium carbonate	1,365	1,452	1,129	Hide scraps	163	541	413
Kainite	2,183	540	105	Leather scrap or meal	2,171	16,028	24,606
Manure salts	2,001	260	8	Wool waste	13	1,490	6,847
Nebraska potash	2,344	9,376	7,166	Tartar pomace	2,421	985	224
Cement dust	1,657	3,859	4,820	Peat (dry)	23	1,300	.....
Furnace and flue dust	893	1,920	995	Peat (wet)	1,000	500	500
Alunite	89	2,804	1,155	Peat (n. o. s.)	.....	357	274
Kelp dried	991	1,744	1,956	Peanut meal	211	1,079	219
Kelp ash	635	1,551	1,454	Natural guano	23,941	23,116	15,100
Kelp char	5	222	132	Base goods	179,283	230,464	89,162
Tobacco waste	16,672	19,511	13,533	Other nitrogenous materials	8,777	9,174	5,451
Wood ash and other plant ash	2,881	2,509	3,519	Filler	12,937	16,909	12,641
Manure ash	637	1,356	551	Other materials (n. o. s.)	2,889	2,284	2,753
Feldspar	73	713	707				
Sugar factory waste	708	1,169	2,132				
Other potash materials	9,600	9,087	12,835				

IMPORTS AND EXPORTS OF FERTILIZER INGREDIENTS OF IMPORTANCE IN FOREIGN TRADE.

Exports of phosphate rock, ground or unground, not acidulated.

HIGH-GRADE, HARD ROCK.

[2,240-pound tons.]

Destination.	1913	1914	1915	1916	1917	1918
Europe:	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Austria-Hungary	36,679	23,466				
Belgium	17,603	19,405				
Denmark	6,000	19,200	5,302	4,400		
France	8,400	3,200				
Germany	259,421	241,560	17,838			
Italy	8,775	10,210				
Netherlands	76,630	98,623	3,008			
Norway					3,104	8,356
Portugal		4,800	760	5,663		
Roumania	6,300					
Spain	12,399	20,493	3,421	5,920		
Sweden	23,495	14,720	9,566	28,195	11,559	13,551
United Kingdom—						
England	20,388	3,950	1,100			1,850
Scotland	4,320	9,708	5,010			
Ireland	13,765	6,000				
North America:						
British Honduras				5		
Canada	25			147	300	235
Mexico						10
West Indies—Cuba						45
Total	494,200	475,335	46,005	44,330	14,963	24,047
Recapitulation:						
Europe	494,175	475,335	46,005	44,178	14,663	23,757
North America	25			152	300	290
Europe:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Austria-Hungary	366,790	234,660				
Belgium	176,030	194,050				
Denmark	60,000	192,000	53,020	44,000		
France	84,000	32,000				
Germany	2,594,210	2,415,600	178,380			
Italy	87,750	102,100				
Netherlands	766,300	986,230	30,080			
Norway					31,040	61,210
Portugal		48,000	7,600	56,630		
Roumania	63,000					
Spain	123,990	204,930	34,210	59,200		
Sweden	234,950	147,200	95,660	267,753	115,858	99,677
United Kingdom:						
England	203,880	39,500	11,000			9,250
Scotland	43,200	97,080	50,100			
Ireland	137,650	60,000				
North America:						
British Honduras				50		
Canada	250			1,497	3,607	3,513
Mexico						108
West Indies—Cuba						615
Total	4,942,000	4,753,350	460,050	429,130	150,505	174,373
Recapitulation:						
Europe	4,941,750	4,753,350	460,050	427,583	146,898	170,137
North America	250			1,547	3,607	4,236

Exports of phosphate rock, ground or unground, not acidulated.

LAND PEBBLE.

[2,240-pound tons.]

Destination.	1913	1914	1915	1916	1917	1918
Europe:	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Austria-Hungary		3,000				
Belgium	106,998	129,537	11,800			4,769
Denmark	15,950	6,200	9,000			
France	113,014	159,927	5,900	14,537	14,536	10,438
Germany	104,470	122,316	5,550			
Italy	78,172	114,601	22,055	2,864	6,069	1,440
Netherlands	77,293	124,579	15,084	45,289	28,686	
Portugal		4,800		3,500		
Spain	54,599	53,928	51,839	75,987	61,897	32,359
Sweden	18,960	34,400		23,280	17,867	4,357
United Kingdom—						
England	83,584	104,840	49,642	34,656	16,794	28,115
Scotland	30,800	13,980	10,070	19,876	4,699	5,100
Ireland	22,300	40,400	33,400	31,483	17,540	4,000
North America:						
Canada	4,366	118	3,000	3,734	4,004	5,545
West Indies—Cuba					6,002	14,786
Asia—Japan	67,392	88,004				
Oceania—British—Australia			5,132			
Total	777,898	1,000,630	222,472	255,206	178,094	110,909
Recapitulation:						
Europe	706,140	912,508	214,340	251,472	168,088	90,578
North America	4,366	118	3,000	3,734	10,006	20,331
Asia	67,392	88,004				
Oceania			5,132			
Europe:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Austria-Hungary		18,000				
Belgium	641,985	765,210	67,300			16,930
Denmark	95,800	37,200	48,000			
France	674,284	943,603	35,400	52,977	38,648	41,774
Germany	607,224	694,146	30,300			
Italy	451,160	669,556	122,030	17,184	16,387	4,320
Netherlands	451,558	731,780	83,907	254,454	130,779	
Portugal		28,800		21,000		
Spain	317,554	313,968	307,640	412,662	263,022	151,467
Sweden	113,760	206,400		123,012	88,261	24,055
United Kingdom—						
England	493,111	621,740	293,622	172,244	47,765	119,502
Scotland	181,800	83,880	58,800	97,040	20,300	18,337
Ireland	119,100	219,600	186,100	154,037	63,531	15,000
North America:						
Canada	26,274	562	18,000	20,267	15,229	21,511
West Indies—Cuba					21,329	43,487
Asia—Japan	404,352	523,524				
Oceania—British—Australia			25,660			
Total	4,577,962	5,857,969	1,276,759	1,324,877	705,251	456,383
Recaptulation:						
Europe	4,147,336	5,333,883	1,233,099	1,304,610	668,693	391,385
North America	26,274	562	18,000	20,267	36,558	64,998
Asia	404,352	523,524				
Oceania			25,660			

Imports of nitrate of soda from Chile, 1909 to 1918, inclusive.

Year.	Quantity.	Value.	Year.	Quantity.	Value.
	Tons.	*Dollars.*		*Tons.*	*Dollars.*
1909	329,124	11,296,083	1914	561,209	17,808,763
1910	538,119	16,225,296	1915	577,120	16,355,595
1911	528,435	16,244,812	1916	1,067,005	31,911,384
1912	475,560	15,123,210	1917	1,261,659	44,231,240
1913	573,778	19,942,419	1918	1,606,498	70,103,459

Value of imports of bones, hoofs, and horns, unmanufactured.

Origin.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Europe:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Austria-Hungary	1,134	8,287	10,359	892	597	53	157			
Belgium	61,258	75,523	94,622	65,361	51,837	31,414				
Denmark				7	3		10			
France	14,997	28,788	10,791	22,454	10,339	15,836	3,389	19,262	2,112	4,134
Germany	46,209	49,874	103,397	73,187	55,783	37,693	4,633	57		
Greece							1,551			
Italy	80	110		2,870	318	1,313	55	2,287	12	31,890
Netherlands	2,477	4,092	1,965	528	1,316	867	1,017			
Norway		10			5					
Russia in Europe			188	131	64	98				
Spain		8,629	8,444					98		
Sweden					10					
Switzerland				4	63					
United Kingdom—										
England	140,869	222,878	170,252	114,718	147,512	140,103	112,602	107,987	85,183	45,723
Scotland	326	10	123	140	1,264	193	12	56		304
North America:										
Bermuda		11,813			5					
Canada	94,949	96,524	90,038	87,565	108,518	142,850	126,293	131,073	189,016	250,660
Central American States—										
Costa Rica	568	606	283	211	180		492			150
Guatemala		52	514	575	537	590	4,100	26	3	
Honduras		2	2	10			35	10		
Nicaragua	155	63			147	100				
Panama	70	580	675	957	1,326	888	1,691	1,025	3,887	4,734
Salvador	154		867		177	182	227	100		
Mexico	40,447	43,085	57,205	67,632	101,714	69,238	77,068	166,055	99,595	88,934
Newfoundland and Labrador	557	225	659	419	263	586	485	116	279	113
West Indies—										
British—										
Barbados				30					5	
Jamaica	209	174		105				165	209	87
Trinidad and Tobago			45		153	1,379	2,059	607	43	
Other British						21	29	21		5
Cuba	38,203	45,567	44,664	43,811	37,205	48,605	44,666	43,667	50,982	47,748
Danish								4		
Dominican Republic					36			84	98	
Dutch			347	1,063	7,596	3,436	1,208	1,472	32	
Haiti							2,302	1,143	485	
Santo Domingo			130	48						
South America:										
Argentina	225,100	420,837	506,624	493,797	314,866	469,077	450,441	320,725	398,893	670,944
Brazil				133	892	360	7,940	2,789	2,373	5,100
Chile	10						1,260	190	13,040	

Colombia	1,617	603	1,063	335	650	2,001	640	747	1,558	4,253
Ecuador				68					2,174	
Guiana—										
British					21					
Dutch				70						
Peru							219		688	
Uruguay	106,037	48,021	66,996	55,716	38,529	75,304	49,110	49,513	110,401	160,006
Venezuela	160	460	1,552	2,722	2,992	6,144	4,750	5,069	11,271	7,132
Asia:										
Aden	4	25				6			973	333
China	559	353	262	1,842	73	267	359	6,442	2,062	
East Indies—										
British—										
British India	35		5	299	15	4,903	7,287	4,813		
Straits Settlements		10	2							
Other British			2							
Dutch	60	61					401		371	14
Hongkong	583	473	617	626	548	496	758	760	3,366	4,626
Japan	62	2	52	39	276		67		632	
Russia in Asia				70		206	74			
Siam								539		
Turkey in Asia						7				
Oceania										
British—Australia				115		7,162	164		217	34,659
French		75								
Philippine Islands	5	5	30	103	50	15	25	33	65	
Africa:										
British Africa—										
West								220		
South	37	4	18			72		41	1,488	12,997
East	426	90	75			1				
Egypt			1,056		13			46		
French Africa							3,867		6,000	
Portuguese Africa							30		31	
Total	777,357	1,067,911	1,168,924	1,038,653	885,893	1,061,466	911,473	867,242	987,544	1,374,546
Recapitulation:										
Europe	267,350	398,201	395,141	280,292	269,111	227,570	123,426	129,747	87,307	82,051
North America	175,312	198,691	195,429	202,426	257,857	267,875	260,655	345,568	344,634	392,431
South America	332,924	469,921	576,235	552,841	357,950	552,886	514,360	379,033	540,398	847,435
Asia	1,303	924	940	2,876	912	5,885	8,946	12,554	7,404	4,973
Oceania	5	80	30	218	50	7,177	189	33	282	34,659
Africa	463	94	1,149		13	73	3,897	307	7,519	12,997

Value of exports of bones, hoofs, horns, and horn tips, strips, and waste.

Destination.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
	Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Europe:										
Austria-Hungary		205								
Belgium	56,045	12,384	36,105	24,733	12,148	9,136	37			
Denmark	134	103	52	92	294	167	183	1,620	655	
France	28,518	15,913	5,404	21,966	24,790	3,241	2,900	14,715	8,985	
Germany	6,522	3,387	11,276	8,365	3,423	6,725				
Gibraltar	45									
Italy	29,789	24,896	11,498	18,034	41,168	11,383	1,060	2,579	1,206	
Netherlands	3,211	2,300	9,682	10,126	15,817	6,751	1,265		8	
Norway									35	
Russia (in Europe)	450	450	310	1,758	410		300	1,772		
Spain	68	290	195						525	
Sweden				59		155		132		
Switzerland							50	10		
United Kingdom—										
England	45,994	46,117	36,840	22,950	28,723	24,617	9,082	13,944	9,186	
Scotland	50			45		120	140		90	
North America:										
Bermuda	72	49			154	7	36	26	175	
British Honduras	3	14	9		171			42	65	
Canada	33,087	16,530	4,315	9,853	7,587	7,607	2,413	9,865	41,492	
Central American States—										
Costa Rica	200	106	760	60		47	328	7	207	
Guatemala				8				279	127	
Honduras	2		11		3	15	39	104	70	
Nicaragua			19		20		4	181	188	
Panama	774	738	121	15	267	64	81	622	727	
Mexico	2,411	766	463	293	86	2	9	2,302	14,640	
Newfoundland and Labrador				27		26		140	648	
West Indies:										
British—										
Barbados	3,158	2,400						9	27	
Jamaica			8				8	227	129	
Trinidad and Tobago			2,015				6	83	13	
Other British				22	26		16	118	150	
Cuba	293	1,242	1,255	851	1,418	2,105	1,891	3,395	5,660	
Danish	230						60	16	58	
Dominican Republic					4	20	130	911	4,307	
Dutch		99		21			3	27	20	
French		6						22		
Haiti		27	55				12	139	319	
Santo Domingo	1,318	659	36	135						
South America:										
Argentina		10					35	1,682	5,097	
Brazil						6	899	1,408	2,445	

Colombia	316			19	952		34	958	1,999	
Ecuador		1,065		22	242	37	27	188	1,101	
Guiana (British)		37						5	68	
Peru							44	12	808	
Venezuela				38	166			102	591	
Asia:										
China						350		36	911	
East Indies—										
British—										
British India			75				16		126	
Hongkong	110	760	150		190	152		3,700		
Japan	19,610	17,154	26,110	38,077	41,678	33,160	24,147	30,175	30,755	
Russia (in Asia)		700								55
Oceania:										
British—Australia	218			13		48	984	688	1,416	
New Zealand		500		21			282	43	11	
Philippine Islands		1,371	5,403	4,406	544	2,890	4,262	11,604	3,918	
Africa—British:										
West									637	
South		93						15		
Total	232,628	150,371	152,167	162,009	180,281	108,831	50,971	105,094	143,281	
Recapitulation:										
Europe	170,826	106,045	111,362	108,128	126,773	62,295	15,017	35,285	20,670	
North America	41,548	22,636	9,067	11,285	9,736	9,893	5,036	18,549	69,114	
South America	316	1,112		79	1,360	43	1,234	4,934	15,164	
Asia	19,720	18,614	26,335	38,077	41,868	33,662	24,163	33,976	32,279	
Oceania	218	1,871	5,403	4,440	544	2,938	5,528	12,335	5,392	
Africa		93						15	642	

Value of imports of dried blood.

Origin.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
	Dollars.	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Europe:										
Austria-Hungary		13,848	19,973	7,107		10,396				
Belgium		8,048	68,750	2,265		93,621	7,473			
Denmark			904							
France		32	11,557			52			24	
Germany	842	114	6,941	6,272	8,668	18,209	359			
Netherlands			2,913	3,661						
United Kingdom—										
England	64,177	36,794	76,555	61,049		80,940	34,114	10,858		22,370
Scotland		12,974	18,093	12,068		17,074	2,437			883
North America:										
Canada	2,381	4,244	1,612		7,181	6,158	2,737	5,157	144	2,729
Mexico	4,447	8,248	6,953	9,096	3,088	7,436	25,065			1,990
West Indies—Cuba		1,425								
South America:										
Argentina	11,478	112,875	189,733	67,609	25,496	96,373	63,719	95,826	313,785	321,524
Chile										300
Uruguay		7,161	6,834	4,179	2,376	12,751	10,535	27,515	50,803	107,128
Venezuela							127	350		1,154
Asia:										
China							480			
Japan										500
Oceania:										
British—Australia	8,380	15,824	35,880	41,949	33,336	48,806	80,152	51,806	24,699	4,125
New Zealand								4,788		
Africa—Egypt								300		
Total	91,705	221,587	446,698	215,255	80,145	391,816	227,198	196,600	389,455	462,703
Recapitulation:										
Europe	65,019	71,810	205,686	92,422	8,668	220,292	44,383	10,858	24	23,253
North America	6,828	13,917	8,565	9,096	10,269	13,594	27,802	5,157	144	4,719
South America	11,478	120,036	196,567	71,788	27,872	109,124	74,381	123,691	364,588	430,106
Asia							480			500
Oceania	8,380	15,824	35,880	41,949	33,336	48,806	80,152	56,594	24,699	4,125
Africa								300		

Imports of sulphur ore, as pyrites, or sulphuret of iron, containing in excess of 25 per cent of sulphur.

[2,240-pound tons.]

Origin.	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918
Europe:	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Germany						1,200				
Portugal	71,839	86,264	117,996	117,914	118,732	102,150	57,109	46,351	16,475	2,700
Spain	545,448	601,536	742,758	840,229	814,534	638,711	687,812	1,207,323	747,866	596,583
United Kingdom—England						16				1,959
North America:										
Canada	43,882	39,500	29,977	37,103	31,293	79,141	99,738	120,896	171,268	205,163
Newfoundland and Labrador			3,548			1,335				3,670
West Indies—Cuba		2,202		50		2,200				
South America—Brazil						7,381				
Asia—Japan	100		2					471		
Total	661,269	729,502	894,281	995,296	964,559	832,134	844,659	1,375,041	935,609	810,075
Recapitulation:										
Europe	617,287	687,800	860,754	958,143	933,266	742,077	744,921	1,253,674	764,341	601,242
North America	43,882	41,702	33,525	37,153	31,293	82,676	99,738	120,896	171,268	208,833
South America						7,381				
Asia	100		2					471		
Europe:	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*	*Dollars.*
Germany						3,354				
Portugal	244,970	291,083	391,375	390,969	392,296	333,978	189,710	151,455	53,425	7,700
Spain	2,064,276	2,197,613	2,609,457	3,388,029	3,632,392	2,966,682	3,531,048	6,489,892	5,170,447	3,709,368
United Kingdom—England						149				6,638
North America:										
Canada	152,467	131,121	91,392	140,202	86,948	312,575	386,491	473,625	632,041	765,429
Newfoundland and Labrador			15,840			2,410				33,200
West Indies—Cuba		6,888		250		21,230				
South America—Brazil						54,957				
Asia—Japan	500		25					6,652		
Total	2,462,213	2,626,705	3,108,089	3,919,450	4,111,636	3,695,335	4,107,249	7,121,614	5,855,913	4,522.335
Recapitulation:										
Europe	2,309,246	2,488,696	3,000,832	3,778,998	4,024,688	3,304,163	3,720,758	6,641,337	5,223,872	3,723,706
North America	152,467	138,009	107,232	140,452	86,948	336,215	386,491	473,625	632,041	798,629
South America						54,957				
Asia	500		25					6,652		

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 799

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER November 10, 1919

A STUDY OF THE ROTS OF WESTERN WHITE PINE.

By James R. Weir, *Forest Pathologist*, and Ernest E. Hubert, *Scientific Assistant, Office of Investigations in Forest Pathology, Bureau of Plant Industry, Missoula, Mont.*

CONTENTS.

LOSSES DUE TO FUNGI.

The estimated stand of western white pine (*Pinus monticola*) in British Columbia, Oregon, Washington, Idaho, and Montana is about 23,685 million feet B. M., valued at approximately $102,875,000. The average loss due to the activities of fungi in western white pine for the entire white-pine belt, based on data from logging operations in northern Idaho, is 1,658 million feet B. M.[1] This figure, on a basis of the above given valuation, shows a loss of $7,201,250 from this cause alone. These figures, taken as an average condition throughout the merchantable range of the species, indicate the loss from decay to be enormous. The limited area occupied by merchantable white pine, the adaptability of its wood to a wide range of uses, and the ease with which it is worked so establish its value as a timber tree that it becomes imperative to investigate any cause of financial loss in the species, the amount of this loss, the

[1] Based on the recorded data, which give 6.9 as the average rot percentage for the entire area upon which the data were collected. The actual loss due to rot would no doubt be greater if figured on a basis of cull percentage or actual volume discarded, according to scalers' practice.

relation of various factors to the rots, and the means by which the loss may be reduced. This, in short, states the purpose of this bulletin.

LOCAL PATHOLOGY OF WESTERN WHITE PINE.

With the exception of the principal fungus (*Echinodontium tinctorium*) attacking western hemlock and grand fir, all fungi occurring on other trees of the western white-pine type attack white pine to a greater or lesser degree. Until it is determined that the interrelations of these fungi vary with different species of trees the conditions for fungous development may be considered very favorable. The western white-pine type of forest is described as having western white pine as the key tree and forming approximately 15 per cent or more of the stand. In some parts of its range (northern Idaho) in young stands western white pine forms as much as 50 per cent or more of the stand. The other species in the mixture are grand fir and western red cedar, the predominant trees of the type, and Douglas fir, western larch, western yellow pine, and lodgepole pine. In many of the mixtures of the western white-pine type, the white pine, although intermediate as to tolerance, very rapidly gains on its associates and eventually overtops them or may even drive them from the stand. One of the results of this suppression of associate species is to promote the activities of fungi in the associate species, which in turn react on the white pine. Fully stocked or even pure stands of western white pine may be found extensively attacked. In the fully stocked stands the trees do not prune readily, causing the development of larger and older dead branches which are open to breakage and infection at an earlier age and also affecting the grade of lumber of the tree. In the pure stands, much suppression naturally results and fungous diseases are just as prevalent as in a mixed stand. Suppression in white pine is not always brought about by overcrowding or by adverse conditions on sites having little protection. Needle fungi may cause retardation by destroying the needles. *Lophodermium pinastri*, in its ascigerous stage and also in its pycnidial stage (*Leptostroma*), is a very common needle fungus throughout the white-pine type and is a factor to be considered in suppression. Mistletoes rarely attack white pine within its merchantable range and may be overlooked as a cause of suppression.

The three main wood-destroying fungi[1] for the areas studied are *Trametes pini*, *Polyporus schweinitzii*, and *Fomes annosus*. The first-named fungus, as the most important, is particularly active in western white pine throughout its merchantable range.

[1] Weir, J. R., and Hubert, E. E. Forest disease surveys. U. S. Dept. Agr. Bul. 658, 23 p., illus. 1918.

The sporophore (conk) of *Trametes pini* (ring-scale fungus) is brown, woody, usually stratified, and varies in shape and thickness. The usual form in the Northwest is a thin shell or scallop shaped structure, but it may become hoof shaped or resupinate, depending upon the position of the substratum or point of exit. Owing to the tendency of the mycelium to spread more rapidly vertically than horizontally in individual annual rings, a cross section of an infected tree shows the decay in the form known as ring-rot. The wood when first invaded by the mycelium of *Trametes pini* assumes a deeper reddish brown than when normal. It first becomes visibly characteristic with the appearance of pits in the wood lined with cellulose fibers. This is the well-known "honeycomb" stage and is the most characteristic stage of the rot. The decay, as indicated above, is not uniformly distributed in the heartwood, but the rot column may vary in location within the tree. This is also due to the fact that several separate infections may occur in the same tree, the diseased areas being separated by sound wood. As a butt rot, the general form of the rot column is conical, tapering at the upper limits. In the upper parts of the tree the rot column may be conical in both directions from the area of greater decay or from the point of first infection. The range of the vertical extent of the rot column in the tree may be from a few feet to the entire length of the tree when acting as a trunk rot and from 5 to 6 feet as a typical butt rot. External signs of the decay are the fruiting bodies, swellings of the trunk in a region of earlier infections, especially at branch whorls, due to the tendency of the tree to heal the old "punk knots," resin flow at swelled whorls or other points on the upper trunk, brownish punky material in old branch knots from which old sporophores have fallen, hollowness or punkiness indicated by soundings on the trunk, and the presence of various injuries.

Polyporus schweinitzii (velvet-top fungus) is usually not as conspicuous as the ring-scale fungus, owing to the fact that the sporophore rarely appears on the trunk but usually develops on the roots near by, and it may be partly obscured by the forest mold. It often appears a considerable distance away from the base of the tree. The fruiting body is in most cases stalked, the segments of the top incurving and colored a deep, rich brown. The margins when in a growing condition are of a lighter color. It sometimes appears from old wounds on the trunk in the form of brackets with or without a lateral stalk. The under side of the pileus is yellowish green, which turns reddish if injured. The fungus usually produces a uniform heart-rot of the butt of the tree. It enters the roots and decays the heartwood and may travel in this manner from root to root to neighboring trees. The decay produced is a light reddish

brown in early stages, but in its typical stage it becomes reddish brown, brittle and crumbly when dry, with a tendency to break into cubical blocks. The rot has sometimes the characteristic odor of turpentine. The rotted wood is carbonized by the action of the fungus and the cellulose is reduced.

The rot caused by *Trametes pini* is characterized by the delignification of the wood cells attacked. White patches of unreduced cellulose are left. The decay produced by *Polyporus schweinitzii* seldom advances beyond the first log and is usually not more than 5 to 6 feet up. The form of the rot column is conical from the base of the tree upward.

Fomes annosus (root Fomes) on the areas studied was least important. The sporophores of this fungus are generally found close under the surface attached to the roots and hidden by the forest mold. They are brown above, with a white spore surface and usually very irregular in outline. The early stages of decay range in color from lilac to reddish. In the typical stages the annual layers are separated by the more rapid decay of the summer wood. In a radial section white-pitted areas with black centers may be prominent. Finally the wood is converted into a spongy mass. The fungus causes a resin flow from the base of the tree and the roots. A fine felty mycelium is present under the bark in the early stages of decay. The rot column is uniformly circular in advanced stages and may extend from 6 to 8 feet into the first log.

FIELD STUDIES OF THE ROTS IN WESTERN WHITE PINE.

Field studies of the principal rots of a particular species of tree which aim to develop results of practical importance must necessarily be based on data taken from a large number of felled trees. It was decided that 100 trees of each age class for each of the two types of site would be a sufficiently large number to insure the best results. Seven age classes were determined upon as follows: 41 to 60, 61 to 80, 81 to 100, 101 to 120, 121 to 160, 161 to 200, and 201+ years. These are the age-class divisions used by the Forest Service in silvicultural practice in district 1. The two types of site, slope and bottom, were used, under each of which the seven age classes were ranged. Figuring 100 trees per age class and 7 age classes for each of the two types of site gives a total of 1,400 trees upon which accurate data on each tree are required in order to be fairly certain of the results.

Previous to the opening of the summer logging operations, all information relative to the age classes, sites, and locations of the various sale areas scheduled for cutting in the western white-pine

type in northern Idaho and western Montana during the field season of 1916 were secured. With this information plans were outlined and arrangements made to secure data on as many of the areas as were necessary in order to comply with the outline previously given. Thanks are due to the officers of the Cœur d'Alene National Forest for their helpful cooperation throughout the season.

In all, seven separate sale areas and one private cutting were covered in the study, and data were secured from each. The Lindberg, Honeysuckle, and Cathcart chances, or sale areas, are located within the drainage of the Little North Fork River. The Tent, Silver, and Boro Creeks sale areas are located in the drainage of the main Cœur d'Alene River, near Nelson, Idaho. The Bennett-Miner chance is located on the slopes adjacent to the North Fork of the Cœur d'Alene River, 20 miles above Prichard, Idaho. The private cutting is located near Priest River, Idaho, and is on the Humbird Lumber Company's land. All of the sale areas, with the exception of the private cutting on the Priest River, are located within the general drainage of the Cœur d'Alene River in the Cœur d'Alene National Forest of Idaho. All the areas studied are typical of the western white-pine type of forest.

Data were secured on the trees soon after the trees had been felled and before any of the logs had been removed by the skidding teams. In this manner it was possible to obtain data on a large number of trees each day. The entire tree was always available, and references to all the trees cut on that portion of the sale area included within the study were covered by the data. No selection of individual trees or groups of trees was practiced, the aim being to record accurate information on the general run of the stand according to age class and site. The sawing of the trees into standard log lengths of 8, 12, 14, and 16 feet by the logging crews offered splendid opportunities to obtain the rot dimensions and other data. The infected culled logs of merchantable size were opened up sufficiently to disclose the rotted area. The top portions of the tree beyond the merchantable limit were cut open by the data crew to determine the exact extent of the rot in cases where the rot ran into the top. Cooperation with the logging contractors and foremen aided greatly in keeping ahead of the skidding teams.

For data on the younger age classes not found on the sale areas, special permission was obtained to cut certain small areas of the younger trees on adjacent areas.

The trees on both the sale areas and the young age-class plats were numbered consecutively as they were measured and recorded, the number being placed on the stump, so that no duplication of trees occurred. Similar extensive and intensive data were obtained for

the white-pine study as were secured for the hemlock study,[1] and all available factors were taken into consideration in the final results. Forest descriptions were written for each sale area, and notes were made of the moisture and shade conditions existing on each.

The data obtained from a total of 1,417 trees, of which 135 were grand fir (*Abies grandis*), were first arranged according to site and age class. While in the field it was found that the number of trees needed in the two youngest age classes could be considerably reduced from the 100-tree standard. It was found that the trees on the 41 to 60 age class in both types of sites, slope and bottom, were uniformly free from visible decay. Owing to this condition and to the fact that young white pines of this age class are too small to be merchantable and should not be cut needlessly, it was decided to reduce the number of trees required. In the 61 to 80 age class it was found that the rots were in the beginning stages, and 60 trees per age class for each type of site were considered sufficient. In all the other age classes the number of trees was either above or but slightly below the 100 mark, except in the 121 to 160 age class on the slope sites, where the number was doubled in order to make a comparison between a similar age class and site for two widely separated sale areas, and in the 201+ age class, where it was impossible to find more than the recorded number of trees. There was, fortunately, one sale area which furnished a fairly large number of trees of the very old age class (201+).

Tables were prepared from the data collected, and these will be presented in the order of their consideration in the text. The volumes were figured by means of the Smalian formula. In these tables the word "Infected" as used at the head of certain columns is intended to cover all trees visibly infected. Early stages of infection not determinable by field observations and not measurable as recognized cull are not included.

RELATION BETWEEN ROT AND VARIOUS FACTORS.

AGE.

In Table I are found the data which show the relation between the rot volume and the age class of the stand. These data are separated under heads of "Bottom sites" (upper part of table) and "Slope sites" (lower part of table), and the data under each head are grouped according of the seven principal age classes.

Trunk-rot, indicated in the table by the initials T. R., represents mainly *Trametes pini*. Butt-rot, indicated by the initials B. R., represents *Trametes pini* when acting as a typical butt-rot, but in-

[1] Weir, J. R., and Hubert, E. E. A study of heart-rot in western hemlock. U. S. Dept. Agr. Bul. 722, 39 p., illus. 1918.

cludes *Polyporus schweinitzii* and *Fomes annosus* as well, and *Armillaria mellea* is sparingly represented.

In comparing the slope sites with the bottom sites it is well to keep in mind that the differences in these comparisons are made even more striking by the fact that the average age of the slope type of sites is greater by 14 years than that of the bottom type.

In Table I the average total volume per age class shows a steady increase for both types of site. The trunk-rot for both types also shows a definite increase from the 41 to 60 to the 201+ age class, the bottom sites indicating a greater percentage of rot than the slope sites. The bottom sites for the 61 to 80 age class show 0.8 cubic feet as the average volume of rot and 85 cubic feet for the 201+ age class, as compared to the slope sites, which have 0.055 cubic feet for the 61 to 80 age and 72 cubic feet for the 201+ class. The figures for the average rot volume for the butt rots on the two types of site vary considerably and do not show any consistent increase between the youngest and the oldest age classes. The 161 to 200 age class on the bottom sites runs extremely high, which may be due to the fact that the site from which these trees were taken was very favorable to butt-rot and supported a great deal of *Polyporus schweinitzii.* On the slope sites the average is less for the 161 to 200 age than for the class preceding it. This again must be accounted for by the local environmental differences present in the various areas upon which the trees included in this study were found growing. This is especially true of the 201+ age class on the bottom sites, in which no butt-rot is recorded and where the rot is almost entirely due to *Trametes pini* acting as a distinct trunk-rot.

The " T. R. + B. R." column gives figures for the combined rots, and in general indicates an increase in rot volume and in rot percentage with increased age.

Table I shows computations of the average annual increase in rot volume between the age classes per infected tree. These figures are intended to serve as an approximation of the rate of increase in rot volume during the life of the stand and are used later to determine the infection age.

A study of the relation between sound and infected trees reveals the fact that as the age increased, the percentage of infected trees increased at a quite rapid rate. The bottom sites show the more rapid increase of the two types of site. It is significant to note that the proportions of trees infected for the bottom and slope sites are almost identical, being 55 per cent and 55.3 per cent, respectively. If, in order to remove to a certain extent the source of error due to the larger percentage of trees of the older age class on the slope sites, the averages of the percentages for the different age classes are com-

pared, it is found that the bottom sites show a greater tendency toward favoring fungous development. The average percentage of infected trees for the bottom sites by this method is 52, and for the slope sites 47. On the bottom sites the rot percentage is 7.8, and on the slope sites 6.1. These figures indicate that although a slightly larger percentage of trees was infected (55.3) and although the trees were considerably older on an average on the slope sites, the bottom sites carry the larger rot percentage. Considering the various areas upon which data were taken as a unit, the total volume of rot was found to be 13,359 cubic feet and the total volume of the stand 193,432 cubic feet. This gives a rot percentage of 6.9, or 7.0 figured on a basis of 1,282 sound and infected trees, ranging from the 40 years' growth to the veterans of 450 and more years.

TABLE I.—*Relation of rots to age classes in western white pine on sites of the bottom and slope types.*

[Abbreviations: T. R.=trunk-rot: B. R.=butt-rot.]

Age classes.	Age computations (years).			Average volume (cubic feet).							Number of trees (basis).				
					Rot per infected tree.							Infected.			
								Annual increase between age classes.							
	Average.	Interval between classes.	Percentage of rot for stand.	Total.	T. R.	B. R.	T. R.+B. R.	T. R.	B. R.	T.R.+B.R.	Sound.	T. R.	B. R.	T. R.+B. R.	Percentage.
Bottom sites:															
41 to 60 years	52	....	0	0.99	0	0	0	0	0	0	37	0	0	0	0
61 to 80 years	73	21	.16	30.7	.8	0	.8	.04	0	.04	58	4	0	4	6
81 to 100 years	88	15	.72	82.7	1.7	1.2	1.6	.06	.08	.055	73	38	5	43	37
101 to 120 years	113	25	1.67	150.9	4.2	2.4	4.0	.10	.05	.09	40	63	8	71	64
121 to 160 years	131	18	3.12	196.2	9.5	2.5	9.2	.29	.007	.29	43	83	3	86	67
161 to 200 years	180	49	15.67	203.0	19.0	281.3	33.6	.19	5.7	.50	4	68	4	72	94
201+ years	289	109	18.3	450.5	83.6	135.9	85.0	.59	0	.47	1	37	1	38	97
Total	125	....	7.8	.....	18.1	61.6	21.6	.....	.....	.....	256	293	21	314	55
Slope sites:															
41 to 60 years	48	0	0	2.7	0	0	0	0	0	0	50	0	0	0	0
61 to 80 years	65	17	.06	4.6	.03	.14	.055	.0015	.008	.003	56	3	1	4	7
81 to 100 years	91	26	.37	11.2	.19	.16	.17	.006	.001	.0045	74	11	13	24	24
101 to 120 years	110	19	.45	57.9	.8	.295	.6	.03	.007	.025	59	30	11	41	41
121 to 160 years	137	27	2.34	178.9	5.7	6.0	5.7	.18	.21	.19	61	156	18	174	74
161 to 200 years	164	27	2.36	237.3	7.3	5.1	6.7	.06	.....	.04	17	61	21	82	83
201+ years	343	179	14.67	485.2	76.3	56.0	72.2	.38	.28	.36	1	55	14	69	98
Total	139	....	6.1	.....	17.6	12.9	16.7	.....	.....	.....	318	316	78	394	55.3

SITE.

The western white pine is found in situations which supply sufficient moisture and shade to fill the requirements of the tree. Moisture plays an important part in its establishment and development, and this is emphasized by the fact that the western white pine attains its best growth in the regions where rainfall is plentiful.

In order to get a first-hand impression of the characteristics of western white pine from the point of view of the logger, questionnaires were sent to a large number of lumber and logging concerns operating in the Northwestern States. Out of the total answers received 18 were selected in which the replies to the questions were complete. Most of these answers were received from companies operating in the States of Oregon, Washington, Idaho, and Montana.

In respect to site, most of these answers state that the rot is greatest in trees occurring on flat, low, and poorly drained land, and that the best sites, where trees are freer from rot, are well-drained slopes or benches. Altitudes ranging from 1,500 to 7,500 feet are given as most favorable to healthy stands, and conversely the greatest proportion of rot is found in stands at altitudes below 1,500 feet.

In Table I it is seen that the proportion of rot on the bottom sites (7.8 per cent) is somewhat greater than on the slope sites (6.1 per cent). Apparently, this difference is directly due to the site and corroborates what has already been said in reference to environment favorable to fungous development. The above comparison of rot percentages for the two types of site is made more exclusive when the figures for the percentage of infected trees for each type are considered. The difference, presumably, would have been still greater if the proportion of the trees on sites of the slope type in certain of the older age classes had not been so much greater than for sites of the bottom type. In Table II a comparison is made between two sale areas in the same forest but separated by a considerable distance. The trees occurring on the slope sites only were used, and these were restricted to the age class of 121 to 160 years. A glance at Table II will show that the trees from the Honeysuckle sale area averaged 132 years and those of the Silver Creek sale area 142 years, a difference of 10 years.

TABLE II.—*Comparison of two sale areas of western white pine of the 121 to 160 age class growing on slope sites, showing the relation of rots to site.*

[T. R.=trunk-rot, B. R.=butt-rot.]

Sale area.	Average age (years).	Total volume (cubic feet).				Volume of rot (per cent).			Number of trees (basis).			
		Stand.	Rot.			T. R.	B. R.	T. R. + B. R.	Total.	Sound.	Infected.	
			T. R.	B. R.	T. R. + B. R.						T. R. + B. R.	Percentage.
Honeysuckle.	132	22,172	323.5	96.1	419.5	1.45	0.43	1.89	122	36	86	70.5
Silver Creek.	142	18,095	536.6	1.6	538.3	2.96	.01	2.97	106	24	82	77.3

This indicates a greater number of the older trees of the 121 to 160 age class on the Silver Creek sale area than on the Honeysuckle area. Continuing the inspection of the data in the table it is seen that the total volume of rot, the rot percentage, and the precentage of infected trees for the combined rots are all greater in the case of the Silver Creek area. The difference of 10 years between the average age for the two areas is apparently responsible for the difference in the rot activity just noted and gives further evidence that, the site being similar, the age of the stand affects the amount and percentage of rot as well as the number of trees infected. Eliminating the difference in the average ages between the two sale areas, the slope sites of the two areas should yield more nearly equal values for total volume of rot, rot percentage, and percentage of infected trees.

Another interesting point brought out in Table II is the variation in the amount of butt-rot for the two areas. Very little butt-rot is found upon the Silver Creek area (1.6 cubic feet) in comparison to that found on the Honeysuckle area (96.1 cubic feet).

In Table III comparisons are made between the rot percentages of trees occurring on the slope and bottom sites of the same sale areas. This method of comparison removes all possible variations which might be due to comparisons of plats occurring upon widely separated areas. In general, the figures show a higher rot percentage in trees occurring on the bottom sites than in those growing on the slopes.

On the Bennett-Miner sale area plat 1 was laid out upon the slopes and plat 2 on the bottoms. The bottom sites have a greater average by 38 years and also a greater rot percentage by 6 than the slope sites. In comparing the slope and bottom sites of the Silver Creek plat 1 area it is seen that the difference in average age is only 4 years, while the difference in rot percentage is approximately 5. Again, in comparing the Honeysuckle plat 1 with the Honeysuckle plat 4 area the difference in average age is 7 years and that of the rot percentage 4.5. The greatest difference in rot percentage is found in comparing the Humbird area with the Tent Creek area, between which are found differences of 39 years in average age and 7 per cent in the rot. This last comparison is not as dependable as the ones preceding, since the slope and bottom areas compared were taken from two widely separated sale areas. Similar criticism also applies to the comparison of the Honeysuckle plat 3 with the Silver Creek plat 2 area, which comparison indicates the possibility that the difference in average age may not be entirely responsible for the small rot percentage in the Honeysuckle plat 3 area. Comparing the same Honeysuckle plat 3 area with the Honeysuckle plat 1*a* area it is seen that a difference in rot percentage of 0.538 is more than balanced by a difference of 50 years, which latter is no doubt accountable for the larger rot percentage found on the slope sites.

Table I shows that for each type of site the rot percentage gradually increases from the youngest to the oldest age class, reaching 18 per cent in the bottom sites and 14.7 per cent on the slope sites. Comparing similar age classes of the two types of sites, the figures for rot percentage on the bottom sites run consistently higher than those of the slope sites.

TABLE III.—*Comparison of bottom and slope sites of different sale areas of western white pine, showing the relation of rots to site, independent of age classes.*

Sale area.	Bottom sites.				Sale area.	Slope sites.			
	Plat No.	Number of trees (basis).	Average age (years).	Rot (per cent).		Plat No.	Number of trees (basis).	Average age (years).	Rot (per cent).
Bennett-Miner	2	15	379.1	20.53	Bennett-Miner	1	71	340.6	14.62
Silver Creek	1	18	146.4	8.01	Silver Creek	1	100	142.2	2.98
Honeysuckle	3	70	72.0	.002	Silver Creek	2	149	79.0	.63
Do	1	347	111.0	5.23	Honeysuckle	1a	16	122.0	.54
Humbird	.....	120	159.6	9.32	do	4	33	118.0	.70
					Tent Creek	.....	241	120.7	2.19
Total	.....	570	.....	.....	Total	.....	712	.....	.....

In comparing the average volume of rot for the two types of site in Table I a striking contrast is found between the butt-rot volumes. The average butt-rot volume on the bottom sites is found to greatly exceed the average volume for the slope sites, the average volume of trunk-rot is approximately equal, while the average volume of combined rots is shown to be somewhat larger on the bottom sites.

INFECTION AGE.

The average infection age, as defined in a previous work,[1] represents the average age of the youngest trees in the stand open to first infection by fungous enemies. It is the average age at which the stand is most liable to first infection and below which infection rarely occurs. Subsequent to this age infection is to be guarded against, as the chances of infection, up to a certain point, will continue to increase with the increase in age, number of injuries, etc.

In this bulletin the term *age of earliest infection* is used in place of "average infection age." It is believed the newer term will more accurately convey the meaning intended.

On the bottom sites, Table IV, the age of the earliest infection for the combined trunk and butt rots can be placed approximately in the 61 to 70 age class, since the first tree with visible decay is found in the 71 to 80 age class and is 73 years old. It must be remembered that actual infection is expected to take place some time before visible

[1] Weir, J. R., and Hubert, E. E. A study of heart-rot in western hemlock. U. S. Dept. Agr. Bul. 722, 39 p., illus. 1918.

decay is present in the tree examined, and this fact would tend to place the age of earliest infection somewhat below the age of the tree at the time visible decay is noted.

TABLE IV.—*Relation of rot to age classes, with reference to the infection age of western white pine on sites of the bottom and slope types.*

Age class.	Bottom sites.					Slope sites.				
	Average age (years).	Number of trees (basis).			Average rot per infected tree (cubic feet).	Average age (years).	Number of trees (basis).			Average rot per infected tree (cubic feet).
		Total.	Infected.	Percentage infected.			Total.	Infected.	Percentage infected.	
41 to 50 years	48	16	0	0	0	45	33	0	0	0
51 to 60 years	56	21	0	0	0	56	17	0	0	0
61 to 70 years	66	21	0	0	0	63	48	2	4	.035
71 to 80 years	80	41	4	10	.79	74	12	2	17	.075
81 to 90 years	85	80	26	33	1.78	85	46	10	22	.213
91 to 100 years	94	36	17	47	1.38	95	52	13	25	.145

In Table IV the youngest trees found visibly infected on the slope site are in the 61 to 70 age class, and the age of the earliest infection would be found in the 51 to 60 age class. The youngest tree on the slope sites found to have visible decay is 61 years old. From these data it appears that the age of the earliest infection would be found between the ages of 50 and 60 years, and to be reasonably safe it may be placed at approximately 50 years.

Most of the answers received from the logging companies in reference to the question of the age at which western white pine is first infected give 50 years as the approximate age below which very little infection occurs.

It is apparent that factors other than that of site influence the percentage of infections as expressed by the figures in Table I. On the bottom site (Table I), the 61 to 80 age class, with an average age of 73 years, has only 6 per cent of the total trees infected, as compared to 7 per cent on sites of the slope type for a similar age class with an average age of 65 years. Density of stand and injuries such as fire scars could well be responsible for the increased infection of the trees on the slope sites. Farther along in the table it is found that for the bottom sites in the 81 to 100 age class, averaging 88 years, the percentage of infected trees is 37 as compared to 24 for the slope sites with a similar age class, averaging 91 years.

On both the slope and bottom types of site it is found that the 41 to 60 age class is entirely free from visible infection; that is, no measurable rot recognizable to the naked eye was found in these trees. This fact alone would indicate that an age of earliest infection placed at 50 years would be as nearly correct as the practical application of such an age demands. The site, apparently, is not the

determining factor as to the earliest age when infection may take place. The earliest visible infection for the groups of trees included in this study was found in a tree on the slope type of site, 61 years old. Table I shows that in the 61 to 80 age class the greater percentage of infected trees is found on the slope sites, while the bottom sites have the larger rot percentage.

INJURIES.

Since injuries play the principal rôle in the infection of living trees, it is important to consider them in relation to the various factors such as age and site and especially in relation to the rot volume. In Table V are given the data for bottom and slope sites, respectively, showing the relation of injuries to age class and to site, as well as indicating the percentage of infection traced to the various kinds of injury. The determination of the particular injury which was primarily responsible for the initial infection of the tree was most difficult in many cases, and no doubt a few of the individual decisions may be classed as doubtful. In the main such factors as the appearance of sporophores and the location of the largest ones, the region of greatest decay within the trunk, and the overwhelming occurrence of butt-rot in trees having large fire scars at the base give substantial evidence for the determination of most of the injuries responsible for infection.

The basis for the determination of the degree of injury rests on the following standard:

0 = No injuries.
x = 1 to 60 dead branches, no frost cracks, and very few miscellaneous injuries (less than 2).
xx = 61 to 120 dead branches, one frost crack, and a superficial blaze, logging scar, or other slight injury.
xxx = 121 to 180 dead branches, not more than 2 frost cracks, deep blazes, logging scars, or fire scars; slight lightning injury.
xxxx = 181 to 250 and more dead branches, more than 2 frost cracks, and heavy injuries (injured and broken top, severe lightning, and other injuries)

Dead branches were considered of prime importance in determining the degree of injury for individual trees. Fire scars proved an exception in a certain group of trees where the fire had caused injuries at the base, and these injuries were believed to be primarily responsible for the entrance of the fungus. These trees were of an age class bearing many dead branches. The younger trees had fewer dead branches than the older ones. Frost cracks were entirely absent in the younger age classes, so that no difficulty was experienced such as would arise in case a tree was found having only 60 dead branches and bearing 2 frost cracks. The older trees bore the few frost cracks found, and these trees had numerous dead branches.

In rating the averages for the various age classes x was given the valuation of 1, xx of 2, etc. In this manner averages such as 0.32 and 2.9 were computed (see Table V), indicating the average degree of injury.

TABLE V.—*Relation of injuries to age and to total stand of western white pine on sites of the bottom and slope types.*[1]

Age class.	Infection traced to—								Total trees with injuries to which infection was traced.		Degree of injury.	Total number of trees.
	Branch stubs.		Broken tops.		Frost cracks.		Fire scars and other injuries.					
	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[2]	Number.	Per cent.[3]		
Bottom sites:												
41 to 60 years	0	0	0	0	0	0	0	0	0	0	0.32	37
61 to 80 years	3	75.0	0	0	0	0	1	25.0	4	6.5	1.74	62
81 to 100 years	23	53.5	0	0	0	0	20	46.5	43	37.1	2.09	116
101 to 120 years	50	70.4	0	0	0	0	21	29.6	71	64.0	2.6	111
121 to 160 years	68	79.1	0	0	1	1.2	17	19.7	86	66.7	2.9	129
161 to 200 years	65	90.3	0	0	2	2.8	5	6.9	72	94.7	2.6	76
201+ years	32	84.2	0	0	2	5.3	4	10.5	38	97.4	3.0	39
Total	241	76.7	0	0	5	1.6	68	21.7	314	55.0	2.4	570
Slope sites:												
41 to 60 years	0	0	0	0	0	0	0	0	0	0	0	50
61 to 80 years	3	75.0	0	0	0	0	1	25.0	4	6.66	.16	60
81 to 100 years	15	62.5	0	0	0	0	9	37.5	24	24.4	.7	98
101 to 120 years	26	63.4	0	0	0	0	15	36.6	41	41.0	1.41	100
121 to 160 years	137	78.7	0	0	1	.6	36	20.7	174	74.0	2.7	235
161 to 200 years	47	57.3	0	0	3	3.6	32	39.0	82	82.8	2.68	99
201+ years	67	97.1	0	0	0	0	2	2.9	69	98.6	3.77	70
Total	295	74.8	0	0	4	1.0	95	24.1	394	55.3	1.9	712

[1] Percentage of total trees (infected and sound) bearing injuries to total trees in stand = 70.
[2] Percentage based on total number of infected trees.
[3] Percentage based on total number of trees.

Table V shows certain interesting results. On both types of site the infections traced to branch stubs bear the largest percentage over infections traced to other injuries, with 77 per cent for the bottom sites and 75 per cent for the slope sites. Broken tops as sources of original infection were not found, although a considerable number of broken-top trees were recorded and some of these trees gave evidence that a certain amount of infection took place through the exposed tip. In nearly every case it was found that infection in the lower part of the trunk had taken place some time previous to the breakage of the top, as indicated by the difference in the stage of development of the two rotted areas. On the bottom sites approximately 2 per cent of the infections were traced to frost cracks and 22 per cent to miscellaneous injuries, which latter included fire scars, blazes, windfall scars, etc. On the slope sites only 1 per cent of the infections were traced to frost cracks and 24 per cent to miscellaneous injuries. On the slope sites a larger percentage of infection traced to miscellaneous injuries is found than is recorded

for the bottom sites. This is due principally to the larger number of basal fire scars recorded for the trees on the slopes. On both types of site a steady increase of the total number of trees with injuries is recorded, ranging on the bottom sites from 0 in the 41 to 60 age class to 97 per cent in the 201+ class. On the slope sites the percentage ranges from 0 in the 41 to 60 age class to 99 per cent in the 201+ class. Comparing the entire stand of each type of site it is seen that the percentage of total trees infected is 55 on the bottom sites and 55.3 on the slope sites. A more correct comparison of the amount of injury found in the stands of each type of site is made by contrasting the percentages of total trees, both sound and infected, bearing injuries. For the bottom sites this percentage is 90 and for the slope sites 70, indicating that a larger number of trees on the bottom sites bore injuries. This difference may be partly due to the presence of a larger number of branch stubs on the trees of the bottom sites. These data clearly indicate the increasing danger of infection through injuries with the increase in age for both sites.

From a study of Table V it appears that frost cracks as sources of infection are more common in the older age classes and not present at all in the younger. The recorded field data show that frost cracks were more frequent in the older trees, which accounts for the preceding statement.

The degree of injury for the two types of site shows a fairly steady increase with increased age and a slight difference in degree of injury for the total stand of the two types of site. The bottom sites have but a few tenths greater degree of injury.

Table V shows that 10 to 30 per cent of the trees are without injuries. These trees are principally in the youngest age classes and bear no dead branches.

SPOROPHORES.

Most of the sporophores encountered in the western white-pine study were those of *Trametes pini*. Very few sporophores of *Polyporus schweinitzii* or of *Fomes annosus* were found attached to the trees. Most of the *Polyporus schweinitzii* fruiting bodies developed on the ground at the base or near the host, and the logging operations nearly always disturbed these from their original positions. A very few sporophores of *Polyporus schweinitzii* were found attached directly to the base of the tree. The data in Table VI, therefore, are principally from field notes on one fungus, *Trametes pini*. In this table it will be noted that the 41 to 60 age class is omitted, since no rot and therefore no sporophores were present on the trees of this class. On the bottom sites out of a total of 533 trees approximately 30 per cent were found bearing sporophores. On these sporophore-bearing trees a total of 604 sporophores were recorded, of which 561,

or practically 93 per cent (92.8), were alive and 43, or over 7 per cent (7.2), were dead, giving an average of 35 sporophores to every 10 trees for the live sporophores, 3 to every 10 trees for the dead sporophores, and an average of 38 sporophores both dead and alive for every 10 trees. An average of 11 sporophores both dead and alive for every 10 trees is found when all the trees of the six age classes are considered. Of the largest sporophores, which varied in size up to 6 by 6 by 8 inches, 92 per cent were found alive and 8 per cent dead. The average of the ages of the largest sporophores is approximately 15 years, and the average height on the trunk is 5.1 feet.

TABLE VI.—*Summary of field notes relating to sporophores on western white pine on sites of the bottom and slope types.*

Age class.	Number of trees (basis).	Number of trees bearing sporophores.	Sporophores.																
			Number.				Largest.						Number for each position on the tree.							
			Alive.	Dead.	Total.	Average per tree.	Average.	Condition. Alive.	Condition. Dead.	Sizes.[a]	Relative position along trunk.	Average height on tree.	North.	South.	East.	West.	Northeast.	Northwest.	Southeast.	Southwest.
Bottom sites:							*Years.*			*Inches.*		*Feet.*								
61 to 80 years	62	2	7	0	7	0.11	5.0	2	0	1 by 2 by 2.	Bottom.	0.8	0	2	1	4	0	0	0	0
81 to 100 years	116	25	71	3	74	.63	5.3	24	1	4 by 3 by 5.	Middle..	1.8	13	10	11	23	1	5	3	4
101 to 120 years	111	46	145	11	156	1.4	13.3	42	4	3 by 5 by 5½.	Top.....	2.0	18	9	14	45	10	7	4	5
121 to 160 years	129	56	273	20	293	2.2	28.5	49	7	6 by 6 by 8.	...do.....	4.5	55	30	57	53	34	11	8	22
161 to 200 years	76	21	47	9	56	.74	19.6	20	1	4 by 6 by 8.	...do.....	6.4	0	13	13	15	0	0	2	10
201+ years	39	9	18	0	18	.46	23.0	9	0	2 by 4 by 6.	...do.....	32.5	0	0	8	8	0	0	0	0
Total:																				
Number	533	159	561	43	604	1.1	15.1	146	13	6 by 6 by 8.	Top.....	.....	86	64	104	148	45	23	17	41
Percentage	.....	29.8	92.8	7.2	.....	.....	.....	91.8	8.2	.....	.....	.....	16.3	12.1	19.7	28.0	8.4	4.4	3.3	7.8
Average[b]	.....	.....	[c] 3.5	[d] .27	[e] 3.8	.....	[f] 15.1	All.	.....	.....	Top.....	5.1	.....	.....	.....	West.	.....	.....	.....	.....
Slope sites:																				
61 to 80 years	60	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
81 to 100 years	98	0	0	0	0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
101 to 120 years	100	7	15	0	15	.15	8.6	7	0	3 by 3 by 3.	Bottom.	2.4	.....	1	10	.....	1	1	1	.....
121 to 160 years	235	105	405	25	430	1.83	11.24	101	4	6 by 4 by 7.	Middle..	3.3	93	45	61	76	23	26	21	57
161 to 200 years	99	23	57	5	62	.62	16.7	21	2	4 by 6 by 6.	...do.....	5.1	12	20	4	9	4	4	4	2
201+ years	70	9	18	6	24	.34	17.3	7	2	6 by 10 by 10	...do.....	35.5	.....	.....	.....	14	2	1	1	5
Total:																				
Number	662	144	495	36	531	.8	12.3	136	8	6 by 10 by 10	Middle..	.....	105	66	75	99	30	32	27	64
Percentage	.....	21.7	93.2	6.8	.....	.....	.....	94.4	5.6	.....	.....	.....	21.1	13.2	15.1	19.9	6.0	6.4	5.4	12.9
Average[b]	.....	.....	[g] 3.4	[h] .25	[i] 3.6	.....	[f] 12.3	All.	.....	.....	Middle..	5.5	North.	.....	.....	.....	.....	.....	.....	.....

[a] The size of the smallest sporophore found wherever the presence of large sporophores is noted was 1 by 1 by 1 inch. [b] Per sporophore-bearing tree. [c] 35 to every 10 trees. [d] 3 to every 10 trees. [e] 38 to every 10 trees. [f] Average age of largest sporophores. [g] 34 to every 10 trees. [h] 25 to every 10 trees. [i] 36 to every 10 trees.

In classifying the sporophores according to the positions occupied on the trunk of the host it was found that the largest percentage of them (28 per cent) developed on the west side of the tree, with the smallest percentage (3.3) on the southeast side. Most of the largest ones were found near the upper end of the group on each tree.

On the slope sites, out of a total of 662 trees 22 per cent were found bearing sporophores. In this connection it must be remembered that a much higher percentage of the trees on the slope sites was in the 120 to 160 age class, which bore the maximum number of sporophores. The sporophore-bearing trees carried a total of 531 sporophores both dead and alive, of which 495, or over 93 per cent (93.2), were alive and 36, or nearly 7 per cent (6.8), were dead. These figures give an average for the total stand of 34 live sporophores to every 10 trees, 2.5 dead sporophores to every 10 trees, and 36 live and dead sporophores to every 10 trees. Considering all of the trees of the six age classes given and not limiting the figures to sporophore-bearing trees alone, an average of eight sporophores both dead and alive was found for every 10 trees. Of the largest sporophores, which varied in size from 1 by 1 by 1 to 6 by 10 by 10 inches, 94 per cent were found alive and 6 per cent dead. The average of the ages of the largest sporophores is recorded as approximately 12 years and the average height on the trunk was 5.5 feet. Most of the sporophores on this site were found grouped on the north side of the trunks, 21 per cent being on the north side and the smallest, or 5 per cent, on the southeast side. Most of the largest ones were found at about the middle of each group of sporophores.

In comparing the two types of site some interesting figures are disclosed. The bottom sites, to begin with, have a larger percentage of sporophore-bearing trees and a slightly larger average number both of living and of dead sporophores per sporophore-bearing tree. In the 81 to 100 age class the bottom sites have 22 per cent of the total trees bearing sporophores, while for the slope site there are none. In the 101 to 120 age class on the bottom sites 41 per cent of the total trees were found bearing sporophores, with only 7 per cent in the slope sites. In the 121 to 160 age class are found the maximum figures. In this age class for the bottom sites 43 per cent of the total trees bore sporophores and for the slope sites 45 per cent. The average of the ages of the largest sporophores is also greater on these sites. On the other hand, the slope sites have a greater percentage of the larger sporophores alive than the bottom sites. It is very interesting to find that the percentage of live and dead sporophores to the total number of sporophores is practically the same for both types of site. This would seem to indicate that site does not appreciably affect the vitality of the sporophore, although it apparently affects the number of sporophores produced.

On the bottom sites it is observed that sporophores are recorded for all the age classes, including that of 61 to 80 years. In the slope sites both the 61 to 80 and the 81 to 100 age classes have no sporophores recorded. The first sporophores appear in the 101 to 120 age class. They increase in number in the 121 to 160 age class and decline in the 161 to 200 and the 201+ age classes. The column indicating the average number of sporophores per tree indicates this very clearly. The column recording the number of sporophore-bearing trees shows a similar increase, reaching a maximum in the 121 to 160 age class, and a rapid decline is noted in the two succeeding age classes. These data indicate a maximum of sporophore production attained in the 121 to 160 age class and show the rapidly decreasing numbers of sporophores present on the trees of the two oldest age classes. Two factors are responsible for the decline—first, the fact that the fungus in the tree has reached and passed its maximum development and so produced fewer new sporophores, and second, the fact that in the old-age classes the old sporophores are observed to have died, become loosened from the trunk, and dropped off. The relation of rot percentage to sporophores is evident when compared on a basis of site. On the bottom sites the rot percentage is nearly 8 (7.8, Table I), and an average of 1.1 sporophore per tree or 11 sporophores to every 10 trees is recorded. In the slope site the rot percentage is over 6 (6.1, Table I), and the average number of sporophores per tree is 0.8 or 8 sporophores to every 10 trees. The bottom sites show a greater rot percentage and a greater average number of sporophores per tree.

Another interesting point brought out by the table is the fact that on both types of site the smallest groupings of sporophores were found on the southeast side of the trees.

DISCUSSION OF RESULTS.

From the foregoing data it appears that age is the important factor in determining the amount of rot to be expected in a western white-pine stand. This factor of age is significant in the application of proper silvicultural methods to the care and disposal of the timber. From the forester's point of view two things stand out in considering the stand in relation to rots. The one is the age of earliest infection of the stand, or the period when infection by fungi can first be expected. This is undoubtedly controlled by the formation of heartwood and the appearance of injuries susceptible to infection. This infection age is found to be approximately 50 years for western white pine, and it indicates the period when the young stand is in need of the utmost protection against infection by fungous spores. Infection takes place in this tree earlier than at 50 years in certain individuals,

and, of course, infection continues to take place in all stands after the 50-year period is reached, and no doubt at an increased rate.

The other consideration of importance to the forester is the period in the age of the stand at which the net increment of sound material passes its maximum. This period is more or less indefinite and difficult to express in actual age figures. It depends primarily upon what the forester considers the dividing line between a stand having sufficient sound material to pay a profit for logging and one having so much rot that logging would not be profitable or the profit a small one, all factors considered. From the viewpoint of annual increment the forester has determined that a rotation of 100 to 120 years for western white pine gives a maximum yield.[1] If this holds true, then it also appears that this will mean the cutting of the stand when the average rot percentage for the bottom sites is 1.7 and for the slope sites 0.5. Glancing at Table I it is seen that for both types of site an appreciable increase in the average annual increase in rot volume is recorded between the 101 to 120 and the 121 to 160 age classes.

In the sporophore summaries (Table VI) an apparent maximum point is reached in the 121 to 160 age class in respect to the number of sporophore-bearing trees and to the number of sporphores produced. The 101 to 120 age class would, therefore, represent the age class having, on the average, a stage of development of the rot below the maximum stage for sporophore production. These facts point to the 101 to 120 age class as a possible felling age from the pathological point of view, and it remains to discover whether an average rot percentage of 1.7 on the bottom sites and 0.5 per cent in the slope sites conforms to the most economical logging or whether a higher rot or cull percentage is possible without a sacrifice in the returns on the operation. The next higher age class (121 to 160) records a rot percentage of 3.1 for the bottom sites and 2.3 for the slope sites.

In the relation of age to injuries the data have shown that with increased age comes a greater degree of injury. This is evident for both types of site in all the age classes excepting the 161 to 200, which drops slightly below the preceding age class in degree of injury. It is so well understood that increased age brings cumulative risks of greater injury that a discussion seems unnecessary.

A steady increase in the number of trees with injuries to which infection was traced is noted with increase in age for both the bottom and slope types of site.

It is readily seen that age up to a certain limit has a definite relation to the sporophore production of a stand. If rot increases with

[1] Mason, D. T. Management of western white pine. *In* Proc. Soc. Amer. Foresters, v. 9, no. 1, p. 61. 1914.

age, then it follows that the production of sporophores will also increase as the decay develops to that stage where fruiting bodies are produced. It is also to be expected that when the period of maximum sporophore production is passed there will be a gradual decline in the numbers produced and also in the numbers retained upon the trunk. Fewer new sporophores are produced in the old-aged trees of the stand, and of the old sporophores already on the tree many die, become loosened from the trunk, and drop off. The data show for both types of site that there is an increase in the number of trees bearing sporophores and in the average number of sporophores per tree, from the 61 to 80 to the 121 to 160 age classes, inclusive, while a decrease is noted for the 161 to 200 and the 201 age classes. This indicates a maximum sporophore production in the 121 to 160 age class and a declining production for the age classes following.

Figures have been given which show that site plays an important part in the development of rot in a stand. The consensus of opinion among practical loggers is that low, flat, and poorly drained sites bear stands having the greatest amount of rot and that the sites where trees are freest from rot or where the rot percentage is small are well-drained slopes or benches. The comparison of slope and bottom sites in respect to rot percentage, both for age classes and for the total stand, indicates that a greater amount of rot is prevalent on the bottom sites. A comparison between trees taken from similar sites upon widely separated areas and having a difference in average age of 10 years shows a difference of 1 per cent in rot between these two areas. The percentage is greater on the area having the greater average age. The same indication is given by the figures for the percentage of infected trees. These data also furnish evidence of the influence of age upon the amount of rot to be found in a stand. Further comparisons of trees occurring on slope and bottom sites on the same sale areas also indicate that the trees on the bottom sites bear a greater percentage of rot than those on the slopes.

In respect to the influence of site upon degree of injury the data do not show conclusively that a greater degree of injury exists upon bottom sites. The bottom sites with 2.4 and the slope sites with 1.9 (Table V) leave too small a difference to attribute them to the influence of site. Apparently greater percentages of infections are traced to branch stubs on the bottom sites than on the slopes. This may be due to the formation of a larger number of dead branches on the bottom sites as a result of greater shade. Light more easily reaches the lower branches of trees growing on a slope than of trees growing on the bottom sites, providing the densities are about equal. This might be a possible explanation of the formation of a greater

number of dead branches on trees of the bottom sites. Site is apparently responsible for a greater percentage of sporophores developing on the trees of the bottom sites. An average for the bottom sites gives a distribution of 11 sporophores to every 10 trees, while the slope sites have 8 sporophores to every 10 trees. The proportion of live and dead sporophores to the total sporophores is about equal on each type of site, 93 per cent alive and 7 per cent dead. The proportion of live and dead sporophores to the total, in the case of the largest sporophores, shows a percentage approaching that already given, also showing very little variation in respect to site. A greater number of sporophore-bearing trees are found upon the bottom sites.

METHODS OF CONTROL.

From the study of the data presented, it appears that the control of diseases in western white pine under the present stage of forestry in the Northwestern States will be a difficult matter and subject to extensive rather than intensive methods. The high economic value of the tree and the large amount of loss due to rot are two important factors which make it imperative that steps be taken at least to check the diseases and that attempts be made to reduce the annual loss of sound material brought about by the spread of the casual organisms.

There are two methods of control which present themselves as practicable under the present methods of forest management. These two methods work hand in hand. The first method is primarily based upon the rotation of the stand or the felling age. It is evident from a study of the data presented that if the stand is cut before any sporophores are produced, or before they are produced in any great numbers, the spread of the diseases will be effectively checked. The data show that a certain age class represents the period in the stand which develops a maximum of sporophores. This period in western white pine is represented by the 121 to 160 age class. This age class has 43 per cent of the total trees bearing sporophores for the bottom sites and 45 per cent for the slope sites. Both the next lower and the next higher age classes have smaller percentages for the two types of site than the 121 to 160 age class. If the felling age of western white pine is kept within the 101 to 120 age class there is every reason to believe that the infected trees will be cut down before they reach the age of maximum sporophore production. Most of them will no doubt be cut down before any fruiting bodies whatever appear. This is the most desirable result and is particularly true for the slope sites.

The second method is fundamentally concerned in the strict application of proper pathological marking rules and the consequent re-

moval of all infected slash on the sale areas. The marking rules should provide definite instructions to fit each distinct sale area and should include the consideration of the classification of stands in the western white-pine type and the methods of cutting employed on each. The pathological marking rules should specify the cutting of all diseased trees on a sale area where selection cutting is employed and the retention on clean-cut areas of seed trees free from all root, butt, and trunk rots, as well as from rust and mistletoe. These two recommendations will insure a healthier second growth in the case of selection or improvement cuttings, and in the case of clean-cut areas will insure the reserved seed trees against windfall and windbreak due to fungous activity.[1] In the case of the clean-cut area the retention of sound seed trees will also prevent distribution of diseases by these trees. If seed trees other than western white pine are reserved, the selection of sound trees will prevent infection of young growth by the rust[2] and mistletoe[3] diseases which are peculiar to certain tree species, such as Engelmann spruce and western larch, found in stands of the western white-pine type. The removal of all infected slash left on a sale area after logging is an important part of the successful control of fungous diseases. In order to prevent the spread of the diseases which have caused rot in the trees of the stand all infected slash liable to develop sporophores should be disposed of in such a manner as to check the development of the fungus and thus prevent subsequent sporophore production, or it should be destroyed outright in some manner consistent with economic requirements.

SUMMARY.

Data obtained in a study of the rots of western white pine show the following conclusions as presented in this bulletin:

The three main wood-destroying fungi in the order of their importance are *Trametes pini*, *Polyporus schweinitzii*, and *Fomes annosus*. Most of the rot found in the tree is traceable to *T. pini*.

Trametes pini attacks all portions of the trunk, acting in some cases as a typical butt-rot. *Polyporus schweinitzii* is found to produce a typical butt-rot, and *Fomes annosus* is chiefly confined to the roots and butt of the tree.

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[1] Hubert, E. E. Fungi as contributory causes of windfall in the Northwest. *In* Jour. Forestry, v. 16, no. 6, pp. 696–714. 1918. Bibliography, pp. 713–714.

[2] Weir, J. R., and Hubert, E. E. Notes on forest-tree rusts. *In* Phytopathology, v. 8, no. 3, pp. 114–118. 1918.

——— ——— Notes on the overwintering of forest-tree rusts. *In* Phytopathology, v. 8, no. 2, pp. 55–59. 1918.

[3] Weir, J. R. Larch mistletoe: Some economic considerations of its injurous effects. U. S. Dept. Agr. Bul. 317, 25 p. 1916.

——— Some suggestions on the control of mistletoe in the national forests of the Northwest. *In* Forestry Quart., v. 14, no. 4, pp. 567–577. 1916.

It is found that an average rot percentage of 7 represents the proportion of sound wood rotted by these agencies in the stands of timber classified under the western white-pine type. This represents a loss of $7,201,250, or 1,658 million feet B. M., in the forests of British Columbia, Oregon, Washington, Idaho, and Montana.

The data indicate that the factor of age is prominent in determining the amount and stage of decay in a stand. The age of earliest infection was found to be approximately 50 years for the trees in general for the Cœur d'Alene region of Idaho.

Site is found to have a bearing upon the rot in the stand. The bottom site, in general, is found to be more favorable to the development of fungous diseases. Site, apparently, has no great effect upon the percentage of trees infected, both sites showing approximately the same percentage. A larger percentage of the slope trees were in the heavier infected age classes. This was not the case for the bottom sites, and therefore a direct comparison of the total percentage of trees infected gives figures which are higher for the slope sites than would otherwise be true. In general, a greater rot percentage, a greater percentage of infected trees, a greater amount of butt-rot, a greater degree of injury, and a larger average number of sporophores per tree are recorded for the bottom sites than for the slopes. This indicates that the bottom sites are more favorable to the development of fungous diseases.

With increased age up to a certain point comes an increase in the number of sporophore-bearing trees and an increase in the degree of injury.

The maximum production of sporophores is found to occur in the 121 to 160 age class. The 101 to 120 age class presents, in so far as the rot data show, favorable figures upon which to determine a pathological felling age.

The high economic value of the tree coupled with the large amount of loss annually sustained through heart-rotting fungi makes it highly necessary to attempt control methods.

The loss due to rots may be reduced by the application of control methods aiming to prevent the spread of the organisms causing decay.

Proper pathological marking rules and practical methods for the disposal of infected slash on sale areas are recommended as methods of control.

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 800

Joint Contribution from the Bureau of Animal Industry, JOHN R. MOHLER, Chief, and the Bureau of Plant Industry, WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER June 8, 1920

THE WHORLED MILKWEED (*Asclepias galioides*) AS A POISONOUS PLANT.

By C. Dwight Marsh and A. B. Clawson, *Physiologists*, J. F. Couch, *Pharmacological Chemist, Bureau of Animal Industry*, and W. W. Eggleston, *Assistant Botanist, Bureau of Plant Industry.*

CONTENTS.

PART I.—INTRODUCTION.

HISTORICAL SUMMARY AND REVIEW OF LITERATURE.

The literature relating to *Asclepias galioides* as a poisonous plant is confined to three publications. Glover and Robbins, in 1915,[1] published statements that cattle in western Colorado had been reported as being killed by a plant which they called *A. verticillata*, but that experiments with rabbits had failed to produce results. Glover, in 1917, published the results of some experiments with rabbits, from which he inferred that the plant was not poisonous either when dry or green, but added that cases reported warrant the suspicion that "the whorled milkweed may be a very dangerous poison weed for sheep and cattle." In July, 1918, Glover, Newsom, and Robbins published a somewhat detailed account of the plant and its distribution, gave the history of some cases of sheep

[1] Full titles of articles referred to in the text are given in the list of literature at the end of the paper.

poisoning in western Colorado, and described experiments in feeding sheep and rabbits which demonstrated the poisonous character of the plant.[1]

In preceding years, however, the Department of Agriculture had received many reports of losses of live stock from milkweed. In most cases the species of plant which caused the trouble was not indicated and the reports were so indefinite that the evidence was not considered strong enough to warrant the addition of the plant to the list of stock-poisoning plants. The reports came from not only Colorado but also from New Mexico, Arizona, California, and Oregon. In 1902, J. C. Johnson, of Higbee, Colo., reported the loss of horses from *Asclepias verticillata.*

In October, 1909, Dr. W. E. Howe, inspector in charge of the Denver district, received from Dr. S. C. Babson details of heavy losses of sheep in the neighborhood of Montrose, Colo. The losses were said to have been due to *Asclepias verticillata*, inasmuch as the animals had fed extensively on the plant and it was found in abundance in the stomach contents. Post-mortem examinations were made, and he reported as the only lesion "pale heart muscles, excessive amount of pericardial fluid, and acute inflammation of the outer covering of the surfaces of the brain."

A similar report was made by Dr. Babson to the chief of grazing, Forest Service, Denver, Colo. He said that the plant grew on the banks of irrigation ditches and that it had been traced from the beginning of the Montrose and Delta Canal to the California mesa. He stated, however, that the plant had leaves 3 or 4 inches long and in pairs. From the description it was assumed that the plant had been wrongly determined and that probably the species he had in mind was *Asclepias speciosa.* Some experimental work was undertaken in regard to *Asclepias speciosa* without any definite results.

The attention of the Washington office was again called to the matter by a letter from L. F. Kneipp, district forester, who reported losses of stock from *Asclepias subulata* near Diamond Valley on the Dixie National Forest and asked for an investigation. A package of the plant, which was said to have killed a great number of cattle on the Dixie Forest, was sent to the Bureau of Plant Industry for investigation, but on account of the small quantity of material it was impossible to determine whether the plant was poisonous. The accounts of the losses of animals on the Dixie Forest, however, were so definite that it was planned to make a more thorough field examination. Meantime, in 1910, Mr. Balthis, supervisor of the Alamo National Forest, sent in specimens from Alamogordo, N. Mex.,

[1] In the Amer. Jour. of Vet. Med., Vol. XIV, pp. 135–136, Dr. L. H. Pammel, in addition to a review of the bulletin by Glover, Newsom, and Robbins, reports the treatment used by a local veterinarian on sheep poisoned by whorled milkweed near Hotchkiss, Colo.

which were identified as *Asclepias galioides* or *Asclepias verticillata.* He stated that it was known in that region as the "beeweed" and that it was regarded as very poisonous to stock.

A statement was sent to the department from the Coconino National Forest, Arizona, which indicated that considerable numbers of sheep were lost in that locality from poisoning by "milkweed." Assistant Botanist Eggleston, while at Mount Carmel, southern Utah, in 1914, was told by Bishop Sorenson that he had seen calves poisoned by the whorled milkweed.

A trip was made by the senior author in 1916 to New Harmony, Utah, on the edge of the Dixie Forest, where losses were said to occur from *Asclepias subulata.*[1] Stockmen in the neighborhood of New Harmony gave somewhat detailed accounts of the deaths of both sheep and cattle from this milkweed, which grows in abundance near the irrigated lands. Arrangements were made with some of them to send a quantity of the milkweed to the experiment station at Salina, Utah, for experimental work. The material failed to arrive, and consequently the experimental work was not undertaken so early as had been planned.

In the fall of 1917 some Colorado papers gave detailed accounts of the loss of 800 sheep in the neighborhood of Dolores and it was stated that the place where the animals died had been known as a "death patch." From the Montezuma National Forest details were obtained of the losses, which, it appeared, did not occur in Dolores but just east of Cortez. It seems that losses had occurred there in preceding years, but at that time, December 7, 736 head out of 1,000 died and it was supposed that the milkweed was the cause. The locality was visited by the senior author in October, 1918, and a careful examination of the region was made in company with Gordon Parker, supervisor of the Montezuma National Forest, and County Agent Newsom. It was found that the place where the loss occurred in 1917 was an area a short distance from Cortez, in which *Asclepias galioides* grows in great abundance. Mr. Newsom said that deaths had occurred repeatedly on this area and that within 3 or 4 years from $35,000 to $45,000 worth of sheep had been lost. This case was reported also by Glover, Newsom, and Robbins. It was found that there were thick patches of the weed in other localities near Cortez, and that there had been other cases of poisoning. From stockmen it was learned also that there had been serious losses near Dolores.

The Grand Junction (Colo.) Daily Sentinel of March 20, 1918, reported that about 60 head of sheep near Whitewater, Colo., had been poisoned by hay which contained milkweed. The case was investigated in the following May by a member of the department's

[1] It may be noted that systematic botanists have determined that the milkweed of that locality is *A. galioides,* not *A. subulata.*

force engaged in investigating poisonous plants. It was found that during lambing the sheep were fed Gunnison Valley hay which contained a considerable quantity of *Asclepias galioides*. One hundred and twenty were said to have been fed, and of that number between 50 and 60 died. The symptoms, as described by the veterinarian who was called in, comprised convulsions, rapid pulse and respiration. Nausea and considerable salivation were present. No bloating was noticed. In the autopsy the only lesion reported was hemorrhagic spots on the heart and lungs. These cases, it should be noticed, were due to the dry plant in the hay.

About the middle of June, 1918, a letter was received from Assistant District Forester Hatton referring to a heavy loss of sheep near Hotchkiss, Colo., with the suggestion that the matter might be worth more careful investigation. Hotchkiss was reached on June 14 by the senior author, and the next day, in company with Mr. Bennett, who owned the sheep, Mr. Kreutzer, the supervisor of the Gunnison National Forest, and Fred Hotchkiss, of Hotchkiss, he made an examination of the locality. It was found that 1,600 sheep had been kept on a pasture of about 40 acres in the "Midway" region for a day with no feed except that which could be grazed in the pasture. An examination of the pasture showed that the vegetation was largely sagebrush, alfilaria, and *Asclepias galioides*. A part of the pasture was an abandoned orchard in which milkweed was abundant.

The deaths of the sheep had occurred between 2 and 3 weeks before, and in consequence it was somewhat difficult to determine to what extent the milkweed had been grazed. A careful examination, however, showed that it had been eaten in many places, and as there was little else in the pasture it was assumed that the animals had eaten the weed, and that it was the cause of the loss. At that time the weed was from 8 to 15 inches high, and was in bud but with no flowers. It was stated that the animals did not die in the pasture but that symptoms began to appear 2 or 3 hours after they left it. Some of them lived 12 hours after symptoms appeared. The principal symptoms, according to Mr. Bennett, were violent convulsions, and it was said that the animals would pound their heads upon the ground. Some of the animals became sick as late as 1 o'clock the next day. The total loss was about 400. or about half of those that were sick.

The weed was found in some other localities between Hotchkiss and Paonia, and Mr. Hotchkiss remarked that he had noticed that when hungry sheep fed upon it many of the sheep died, and that when they avoided the milkweed he lost no sheep, so he felt positive that the milkweed was the cause of the loss. The evidence pointed so strongly to the milkweed that it was deemed probable that it was the real cause of the losses.

ASCLEPIAS GALIOIDES. MATURE PLANT FROM HOTCHKISS, COLO., SHOWING FLOWERS AND FRUIT.

ASCLEPIAS GALIOIDES. PLANT FROM HIGH ROLLS, N. MEX., IN FLOWER, WITH ROOT SYSTEM.

ASCLEPIAS GALIOIDES. YOUNG PLANT FROM PAONIA, COLO., IN BLOSSOM, SHOWING LONG ROOT.

A considerable quantity of the plant was collected and sent to the Salina experiment station, where experiments, which were immediately undertaken, proved it to be extremely toxic.

Assistant Botanist Eggleston spent most of July, August, and September, 1918, in investigating the distribution and habits of the whorled milkweed in Colorado, Utah, and New Mexico.

DESCRIPTION OF ASCLEPIAS GALIOIDES.

Asclepias galioides, whorled milkweed. The stems are erect, single, or several, sometimes branching, "near woody" at base, and from 1 to 5 feet high; the main roots are horizontal, often branching, with adventitious buds producing new stems; the leaves are in whorls, from 2 to 6, narrowly linear, from 2 to 4 inches long; the flowers are in umbels from one-half to 1 inch across, at the ends of branches or in the axils of leaves; the 5 greenish-white sepals are ovate, reflexed, and persistent; the petals are united; there is a crown of cornucopialike segments with horns attached between the corolla and stamens; the stamens are 5 in number, and the pollen coheres in a waxy mass which is removed bodily by insects; the pods are from 1 to 3 inches long, narrow, hairy, splitting on the sides; the seeds are flat, reddish-brown, with a tuft of long, silky hairs at summit. It flowers in June and July, the blooms often continuing until September.

Plate I illustrates the mature plant, showing both flowers and fruit. Plate II shows also the root, and Plate III shows the extended root system of even small plants. Plate IV, figure 1, shows the plant growing in an abandoned orchard.

There seems to have been some confusion in regard to the systematic position of the whorled milkweed. Glover, 1917, and Glover, Newsom, and Robbins, 1918, call it *A. verticillata*. The plant collected in southern Utah, as stated on page 3, was known as *A. subulata*. A special study of the subject was made by Mr. Eggleston with the following result:

The whorled milkweeds were named by Dr. Gray, 1886, as follows:

Asclepias mexicana.
Asclepias verticillata.
var. *subverticillata.*
var. *pumila.*

A. galioides was first described by Humboldt, Bonpland, and Kunth, 1818, from the State of Michoacán, Mexico.

Miss Anna M. Vail, 1898, separated the group into 7 species.

Wooton and Standley, 1915, considered *A. galioides* the common New Mexico species of whorled milkweed and then reached the following conclusions in regard to other species:

Our specimens may include *A. verticillata*, but we have been unable to separate them definitely. They also include specimens cited by various authors as

A. subverticillata. In our opinion there is only one species of this type in New Mexico.

The study of fresh specimens in New Mexico, Colorado, Utah, and the examination of dried specimens in the herbaria leads to the conclusion that *A. verticillata* does not occur in the Rocky Mountain country, but is a species of the Atlantic Plains and the Mississippi Valley.

A. mexicana grows from 3 to 5 feet high, and has wider leaves and shorter horns than other species of the whorled-milkweed group. It ranges from southern Mexico through western Arizona, California, and western Nevada to the Columbia and Snake River valleys in Washington and eastern Idaho.

A. pumila (*A. verticillata* var. *pumila*) is a low, tufted plant with leaves irregularly crowded on the stem. The plant, if it proves to be only a variety, belongs with *A. galioides.* It ranges from South Dakota to Colorado, western Nebraska, and New Mexico.

A. galioides was included by Dr. Gray in *A. verticillata.* Recent authors have tried to distinguish the two species by the shape of their hoods, describing those of *A. verticillata* as *entire* from a rear view, and those of *A. galioides* as *hastate-sagittate.*

All the whorled-milkweed flowers seen in the summer of 1918 had entire hoods. Examination of these specimens after drying shows the hoods *hastate-sagittate.* A study of herbarium specimens indicates that hoods of both *A. verticillata* and *A. galioides* are often *hastate-sagittate* when dried. These species, however, differ in two respects. *A. verticillata* has a bunch of long, fibrous roots and smooth pods; *A. galioides* has horizontal main roots and hairy pods, and in these characters agrees with *A. pumila* and *A. mexicana.* In flower the species appear to be nearly identical.

There appears to be no doubt that the plant which has been responsible for the cases of poisoning in Colorado, Utah, Arizona, and New Mexico is *A. galioides.*

DISTRIBUTION AND HABITS OF THE PLANT.

The plant ranges northward from Central America through Arizona and New Mexico to central Utah and central Colorado.

It has been found in Utah as far north as Beaver County (according to Esplin) and the foothills of the Uinta Mountains (according to Jones). In western Colorado it has been seen on Grand River as far up as Glenwood Springs, on the North Fork of the Gunnison River as far as Bowie, and on the Gunnison River to the Black Canyon.

In eastern Colorado it has not been observed north of the Arkansas watershed, but occurs on that river as far as Parkdale, just above the Royal Gorge. Figure 1 shows, in a general way, its distribution.

The natural habitat of *Asclepias galioides* is dry plains and foothills. In the foothills of Colorado and New Mexico it seems best at home in the bottoms of draws. In southern Utah it occurs frequently in sandy, rolling plains. In New Mexico it reaches an altitude of about 7,500 feet and in southern Colorado 7,000 feet.

Its downy seeds are adapted to wind dispersal, but in the irrigated orchards and fields, where whorled milkweed is becoming abundant, the rapid increase has been due largely to water transportation of seeds. The irrigating ditches have proved to be ideal for the transportation, germination, and development of seeds. Wherever ditches have been dug in the neighborhood of whorled milkweed young plants have developed along the water line and spread by means of horizontal roots and seeds. The main ditches carry seeds into the laterals and thence into the open fields. Fortunately the milkweed is a sun-loving plant and does not germinate or grow well in the shade. There is little evidence that it establishes itself in fields with heavy cover crops like alfalfa, but a poorly seeded field may be just the place for it to get a strong foothold. In old orchards where the milkweed gets a start it runs riot, often forming a solid mat between the trees.

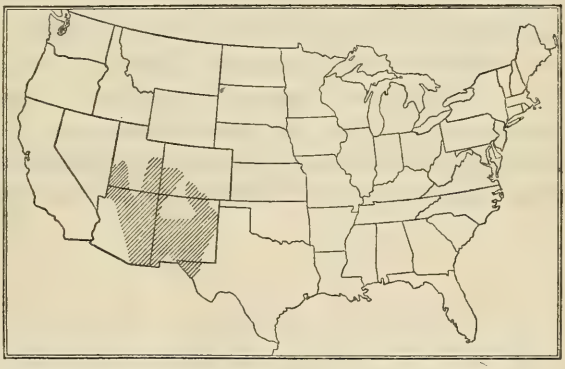

FIG. 1.—Distribution of *Asclepias galioides* in the United States.

The rapidity with which the plant spreads along the ditches is amazing. The orchard country at Grand Junction, Colo., has been ditched by various projects, the last and uppermost of which is the United States Reclamation Service ditch. Lateral ditches from this main ditch, dug in new ground but three years ago, are fringed with milkweed.

In the Grand Junction region much of the stock poisoning is caused by milkweed in the hay. The trees in many milkweed-infested orchards there have been removed and the land sown to alfalfa.

Another orchard country, on the North Fork of Gunnison River, in Delta County, Colo., has no milkweed in its hay, but heavy losses of stock are reported at the time the animals are trailed to and from the summer ranges in the mountains. Ditches and fence rows along these trails often have quantities of milkweed which the stock eat when forage becomes scarce.

Many areas in southern Utah are given up to corn raising by dry-land farming and afford another poison-milkweed problem. Some of the fields are in the natural habitat of the milkweed; cultivated soil forms a better seed bed than the undisturbed soil; cultivation breaks up the horizontal roots and propagates new plants rapidly. Areas of this type may be seen between Kanarraville and New Harmony, Utah.

On some of the overgrazed ranges whorled milkweed has become a menace to stock. The range country in Long Valley on the Virgin River near Mount Carmel, Utah, appears to be an overgrazed range of that sort. Arizona and New Mexico also have the same range trouble.

PART II.—EXPERIMENTAL WORK.

Although both cattle and horses are killed by the milkweed, the greater part of the experimental feeding work was done with sheep, since most of the heavy losses are of sheep, and, moreover, it did not seem wise to kill cattle and horses unless it was distinctly necessary. Enough was done with cattle and horses to demonstrate the toxicity of the plant for those animals and to show that the results obtained from the sheep experiments could be applied to other animals. Table 1 gives a summary of the experiments.

TABLE 1.—*Summary of feeding experiments with Asclepias galioides, 1918.*

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant estimated as green plant for 100 pounds of animal.	Remedy used.	Result.	Where plant was obtained.	Remarks.
Designation.	Weight.								
Horse:	*Pounds.*				*Pounds.*				
No. 126	1,020	July 30	Fed in hay	Green leaves, stems, and buds.	0.22	Arecolin	Very sick, recovered.	Hotchkiss, Colo	
No. 126	990	September 20	do	Dry leaves, stems, and flowers.	.14		Not sick	Paonia, Colo	
Cattle:									
No. 815	430	August 1	do	Green leaves, stems, and buds.	.163		do	Hotchkiss, Colo	
No. 815	448	August 8	do	Dry leaves, stems, and buds.	.22		do	do	
No. 815	449	August 13	do	do	.242		do	do	
No. 815	455	August 17	do	do	.294		do	Paonia, Colo	
No. 750	575	August 22	Fed	Green leaves, stems, and flowers.	.22		do	Grand Junction, Colo	
No. 750	588	August 25	Fed in hay	Partly dry leaves, stems, and flowers.	.626		do	do	
No. 750	593	August 26	do	do	.845		Sick	do	All may not have been eaten.
No. 750	600	September 22	do	Dry leaves, stems, and flowers.	.551	Arecolin	Death	Paonia, Colo	
Sheep:									
No. 480	95.5	June 18	Balling gun	Green leaves, stems, and buds.	.577		do	Hotchkiss, Colo	
No. 478	100.5	June 19	do	do	.165		Not sick	do	
No. 476	81.5	June 20	do	do	.270		Death	do	
No. 465	121	June 21–24	Fed in hay	do	.44		Not sick	do	Not eaten.
No. 509	117	June 20	do	do	.189		do	Paonia, Colo	
		June 21	do	do	.22		do	do	Ate 0.2 pound June 21.
		June 22	do	do	.22		Death	do	
No. 470	93	July 2–14	Balling gun, daily feeding.	Dry leaves, stems, and buds.	.6473		Not sick		Largest dose daily 7.6 grams—25 green—0.058 pound.
No. 475	103.5	August 17	Balling gun	Dry leaves and flowers.	.160		Death	High Rolls, N. Mex	
No. 478	114	August 19	do	Dry leaves	.11		Not sick	do	
No. 490	86	August 21	do	do	.136		do	do	
No. 483	126.5	August 22	do	Dry leaves and flowers.	.138		Death	Paonia, Colo	
No. 506	120.5	August 26	do	do	.132		Not sick	do	

TABLE 1.—*Summary of feeding experiments with Asclepias galioides, 1918*—Continued.

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant estimated as green plant for 100 pounds of animal.	Remedy used.	Result.	Where plant was obtained.	Remarks.
Designation.	Weight.								
Sheep:	*Pounds.*				*Pounds.*				
No. 478	111	August 28	Balling gun	Dry leaves and flowers.	0.138		Not sick	Paonia, Colo.	
No. 478	111	August 29	do	do	.138		do	do	
No. 478	111	September 2	do	do	.147		do	do	
No. 478	111	September 5	do	do	.167	Arecolin	Sick	do	
No. 468	96	September 7	do	do	.166		Death	do	
No. 492	111	September 11	do	do	.165	Arecolin	do	Grand Junction, Colo.	
No. 506	124	September 11	do	do	.148		Symptoms	do	
No. 506	124	September 12	do	do	.151		Not sick	Paonia, Colo.	
No. 437	108.5	September 16	do	do	.168	Atropin and morphin.	Death	do	
No. 506	124	September 16	do	do	.160		Not sick	do	
No. 506	124	September 18	do	do	.172		do	do	
No. 506	124	September 20	do	do	.184	Atropin and morphin.	Death	do	

Summary of feeding experiments with Asclepias galioides, 1919.

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant estimated as green plant for 100 pounds of animal.	Remedy used.	Result.	Where plant was obtained.	Remarks.
Designation.	Weight.								
Sheep:	*Pounds.*				*Pounds.*				
No. 522	87	August 11	Balling gun	Leaves and stems	0.142		Not sick	Palisades, Colo.	
No. 522	87	August 14	do	do	.155		do	do	
No. 522	87	August 16	do	do	.162		do	do	
No. 522	87	August 18	do	do	.169		do	do	
No. 522	87	August 20	do	do	.176		do	do	
No. 521	89	August 22	do	Stems	.147		do	do	
No. 522	87	August 23	do	Leaves and stems	.183		do	do	
No. 523	93	do	do	Leaves	.147		do	do	
No. 522	87	August 25	do	Leaves and stems	.191		do	do	
No. 520	94.25	do	do	Stems	.191		do	do	
No. 526	98.5	August 26	do	Leaves	.161		do	do	
No. 522	87	August 27	do	Leaves and stems	.198		do	do	
No. 486	131.25	do	do	Stems	.206		do	do	
No. 548	109	August 28	do	Leaves	.176		do	do	
No. 522	87	August 29	do	Leaves and stems	.204		do	do	
No. 514	142.25	do	do	Stems	.220		do	do	
No. 534	108.5	August 30	do	Leaves	.191		Slightly sick	do	
No. 522	87	September 1	do	Leaves and stems	.219		Not sick	do	
No. 539	96.75	September 2	do	Stems	.250		do	do	
No. 522	87	September 3	do	Leaves and stems	.232		do	do	
No. 542	110	do	do	Leaves	.198		Symptoms	do	
No. 536	112	September 4	do	Stems	.265		Not sick	do	
No. 522	87	September 6	do	Leaves and stems	.247		do	do	
No. 518	124	do	do	Stems	.279		do	do	
No. 461	102.5	do	do	Leaves	.220	Eserin	Death	do	
No. 482	127.5	September 9	do	Stems	.294		Not sick	do	
No. 522	87	do	do	Leaves and stems	.275		do	do	
No. 372	129	September 10	do	Leaves	.206	Eserin	Sick	do	
No. 522	87	September 11	do	do	.198		Symptoms	do	
No. 556	110	September 13	do	Stems	.309		Not sick	do	
No. 486	136	September 15	do	do	.327		do	do	
No. 547	96.5	September 17	do	do	.367		do	do	
No. 541	102.5	September 19	do	do	.404		do	do	
No. 536	116.5	September 20	do	do	.367		do	Rockville, Utah	

Summary of feeding experiments with Asclepias galioides, 1919—Continued.

Animal.		Date of feeding.	Method of feeding.	Part of plant used.	Weight of plant estimated as green plant for 100 pounds of animal.	Remedy used.	Result.	Where plant was obtained.	Remarks.
Designation.	Weight.								
Sheep—Con.	*Pounds.*				*Pounds.*				
No. 522	86	September 22	Balling gun	Leaves	0.147		Somewhat sick.	Rockville, Utah	
No. 534	112.5	do	do	Stems	.404		Not sick	do	
No. 544	98.75	September 25	do	do	.477		do	do	
Horse:									
No. 126	1,030	August 20 to 25	Fed in hay	Leaves and stems			do	Palisades, Colo.,	Ate only a small quantity.
No. 126	1,050	September 15	do	Leaves	.161		Death	Rockville, Utah	

HORSE EXPERIMENTS.

Only one horse, No. 126, a 5-year-old gelding weighing 1,020 pounds and in fine condition, was used for experimental feeding. At 3.36 p. m. July 30, 1918, the animal was given 1,020 grams, equal to 0.22 pound per hundred weight of animal, of *Asclepias galioides* which had been shipped from Hotchkiss, Colo. The plant was mixed with 5 pounds of alfalfa hay. The feeding was entirely eaten by 5.15 p. m. of the same day. The horse was kept under observation until 10.30 p. m. and during that time no symptoms appeared. It was seen again the following morning, July 31 at 7.45 a. m., when it seemed slightly paralyzed in its hind legs and while being driven from one pen to another, fell down. At 8 a. m., its pupils were dilated and it was moving uncertainly about the corrals, evidently not having entire control of its legs. When hurried it fell. At 8.30 a. m. it was staggering about the corral; would walk a few steps, tremble, spread its legs apart and fall. As it went down its head was bent toward its breast and its lips were drawn back from its teeth. It perspired freely and the pupils were dilated. These motions were repeated again and again. The animal rose from the reclining posture with difficulty and in its attempt to move about the corral was uncertain in its movements and staggered from side to side. It could stand for only an extremely short time and then would fall and again attempt to rise.

Plate V, figures 1, 2, 3, 4, 5, and 6, show its attitude at various times between 8.25 and 8.45 a. m. Figure 1 shows the attitude assumed during the spasms. The head is extended rather rigidly and the legs drawn close to the body. In figure 2 the animal is shown in a brief period of rest before attempting to rise. Figure 3 shows the characteristic staggering as it attempted to move about the corral. In figure 4 its head is drawn close to the breast, an attitude frequently assumed in the spasms. In figure 5 the horse is attempting to rise. It was noticed in these attempts that it had less control of the hind legs than of the fore legs. These motions were repeated every 2 to 5 minutes and it was noticed that in falling the animal almost invariably fell upon its right side, the head sometimes striking the ground with great violence. Figure 6 shows the animal just as it is attempting to raise its head from the ground.

Plate Va, figure 1, taken at 8.57 a. m., shows the horse in one of its attitudes when attempting to stand. As stated, the animal would fall upon its right side and roll upon its belly and then attempt, with greater or less success, to rise. During this time it breathed with forcible expirations, frequently accompanied with grunts. Figure 2 of the same plate shows the animal again in one of its attempts to get upon its feet. These motions were repeated frequently, the

animal being unable to get upon its feet between about 9 o'clock and 11.30 a. m. Figure 3, taken at 10.30 a. m., shows the horse in the midst of one of its spasms. Figure 4, taken at 11.24 a. m., shows a very characteristic attitude in which the horse draws its head back, baring its teeth. Generally speaking, in the spasms the head was drawn back in the position of opisthotonos, or the head was drawn close to the breast. The animal was not quiet more than 5 or 10 minutes at any time. At 11.39 a. m., it got upon its feet, moved a short distance, and then fell again. This was repeated a number of times before 12 o'clock and at 12.17 it was again able to get upon its feet and staggered across the corral, but immediately fell, going down with considerable violence. This was repeated two or three times before 1 o'clock p. m. Figure 5, taken at 1.03 p. m., shows the animal in one of these brief intervals when he was upon his feet. At 1.35 p. m. it was noticed that the walking movements, which were seen very markedly in sheep, were noticeable and later became more rapid, so that between 2 and 3 o'clock the movements of the legs were much like those made by an animal in running. During this time the animal, when down, was always on its right side and moved its head back and forth upon the ground with such violence as to result eventually in the loss of sight in the right eye.

The condition of the horse remained practically the same through the remainder of the afternoon and evening. The last observation was made at 10.45 p. m. At 2.30, 3.10, and 4.40 one grain of arecolin was given subcutaneously. It was noticed at the last observation in the evening that it would attempt to eat hay which was placed before it. The first observation on August 1 was at 7.15 a. m., and at that time the horse was in practically the same position as when left the night before. When disturbed it rolled upon its belly, but had great difficulty in maintaining that position. At 7.25 it was found standing, being especially weak in the hind legs. At 8 o'clock it walked into the next corral and drank water copiously.

Plate VA, figure 6, taken at 8.45, shows the general attitude of the animal when standing. It continued to improve and remained on its feet during the day, gradually reaching almost complete recovery. It was noticed, however, that at different times, a month later, when he was being driven, he would suddenly fall with considerable violence. It was thought at the time that these falls were partly due to defective eyesight, as he was practically blind in the right eye. As it is possible that a permanent systemic injury was produced by the Asclepias poisoning, the animal was kept under observation another year. Whether the arecolin had any marked effect in aiding in recovery is a matter of doubt. It is a fact, however, that the animal was very sick, and the experience with other animals shows that most cases end fatally. It is possible, therefore, that the

arecolin had some value. This horse was fed *Asclepias galioides* again on September 20, and received 0.14 pound per hundredweight of animal. This was given at 2.05 p. m., and the animal was kept under observation during that and the three succeeding days, but showed no symptoms during that time.

In the fall the horse was taken from the station to a pasture near Salina, where it was kept during the winter. It was reported by the forest ranger who drove the animals down that No. 126 whirled around a number of times, drew its head down and fell, but soon got up and went along. It was also reported that it acted queerly at various times during the winter. It was driven to the station again May 28, 1919, when it was in very good condition. During June and the first half of July, it was repeatedly observed to stop suddenly, whirl about one or more times, draw the head toward the breast, and fall. These fits seemed to come suddenly when the animal was running or excited. In the latter part of July it was fed another species of Asclepias with no effect, and from August 20 to 25 an attempt was made to have it eat *Asclepias galioides*, but with no success.

On September 15, 1919, within about 7 hours, it ate 0.507 pound of dry *Asclepias galioides*, which is equivalent to 0.161 pound of green plant per hundredweight of animal. The material fed consisted of leaves only and was mixed with chopped alfalfa. As shown elsewhere (p. 37) it has been found that the leaves of *Asclepias galioides* are much more toxic than the stems, so that this quantity, 0.161 pound, was really a much heavier dose than that of the preceding year, 0.22 pound, which consisted of stems as well as leaves. The feeding was given at 10.50 a. m. and the above-mentioned amount had been consumed at 5.23 p. m. At that time there were symptoms of intoxication, weakness in the hind legs being especially noticeable. These symptoms gradually became more pronounced until at 7.13 the animal went into a spasm. After that the spasms followed one another at exceedingly short intervals and it exhibited all the symptoms seen in its case the preceding year. It was kept under constant observation until death, which occurred at 12.28 p. m., September 16.

The autopsy was made immediately after death. The stomach was greatly distended with gas, and parts of the wall were deeply congested. There were congested areas in the jejunum, ileum, and cecum. The spleen and pancreas exhibited some congestion. The brain and spinal cord were congested, there were areas of hemorrhage between the medulla and cerebrum, and minute hemorrhagic areas on the surface of the cord. The heart was in diastole; it was unusually large and the walls were flabby.

CATTLE EXPERIMENTS.

Two head of cattle were used in the feeding experiments. No. 815 was fed four times; August 1 it received 0.163 pound of *Asclepias*

galioides per hundredweight of animal; August 8, 0.22 pound; August 13, 0.242 pound, and August 17, 0.294 pound. None of these feedings took effect.

No. 750 also was fed four times. It was a steer that was locoed in 1917, but under continued treatment was practically cured, although not quite in full flesh. The animal would be considered in fair condition. On August 22 this animal received 0.22 pound per hundredweight of animal, which produced no effect. On August 25 it received 0.626 pound per hundredweight of animal, again with no result. In the feeding of August 22 the material was eaten within 4 hours; in the feeding of August 25 it was eaten in about 2½ hours. On August 26 the animal received 0.848 pound per hundredweight of animal, but unfortunately no note was made as to whether all was consumed. No symptoms appeared during the day. On the next day, however, August 27, at 9.13 a. m., it was noticed that the muscles of the fore legs and the neck were quivering in an abnormal manner.

At 12.01 noon the animal fell upon its stomach, throwing the head back and kicking spasmodically with its fore legs. It then lay upon its belly with the forefeet doubled under the thorax and hind legs stretched out, in a position as shown in Plate VI, figure 2. Figure 1 shows the animal just before it fell. It then got up and moved about, staggering and trembling, with its hind legs far apart. At 12.10 it was found moving in an unsteady way with shoulders twitching violently and breathing with grunts. Saliva was dripping from its mouth. Figure 3 shows the attitude at that time. It moved about in a weak way, sometimes turning toward the right, and soon went down again. Figures 4, 5, and 6 show the attitudes which it assumed while attempting to stand. At 12.35 it went down, pushing forward with great violence. Plate VIA, figure 1, shows its attitude as it came down upon the ground. It turned over upon its left side, then back upon its belly with the hind legs extended, but at 12.37 it was again on its feet. Figure 2 shows the animal on its feet again at 12.40. Figure 3 shows how it attempted to move rapidly and had difficulty in maintaining itself. At 12.44 (fig. 4) it started to run and went against the wall of the corral, fell down upon the right side with legs stiffly extended, but rose in a few seconds, and at 12.45 was down again, but at 12.46 was on its feet. At 12.50 it fell, rolled over on its stomach, and then dragged itself along, in its attempts to rise. This position is shown very clearly in figure 5. Figure 6 shows its position at 12.52 p. m. These movements were repeated again and again. It ordinarily remained on its feet not more than 10 or 15 minutes at a time.

At 1.35 p. m., however, the animal seemed quite strong and when made to run around the corral for two or three minutes did not fall, although it still staggered. At 1.57 after being run about it ran into

FIG. 1.—ASCLEPIAS GALIOIDES GROWING IN AN ABANDONED ORCHARD.

FIG. 2.—A YOUNG PLANT OF ASCLEPIAS GALIOIDES GROWING FROM A PIECE OF ROOT ABOUT ONE-FOURTH INCH LONG.

FIG. 1.—Horse 126 at 8.25 a. m., July 31, in a spasm.

FIG. 2.—Horse 126 at 8.30 a. m., July 31.

FIG. 3.—Horse 126 at 8.32 a. m., July 31, attempting to stand.

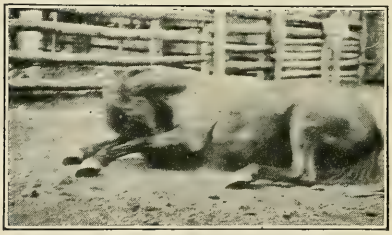

FIG. 4.—Horse 126 at 8.45 a. m., July 31, showing the position with head drawn to the breast.

FIG. 5.—Horse 126 at 8.45 a. m., July 31, attempting to rise.

FIG. 6.—Horse 126 at 8.54 a. m., July 31, attempting to recover from a prostrate position.

FIG. 1.—Horse 126 at 8.57 a. m., July 31.

FIG. 2.—Horse 126 at 9.42 a. m., July 31.

FIG. 3.—Horse 126 at 10.30 a. m., July 31.

FIG. 4.—Horse 126 at 11.24 a. m., July 31.

FIG. 5.—Horse 126 at 1.03 p. m., July 31, when able to get upon his feet for a minute or two.

FIG. 6.—Horse 126 at 8.45 a. m., August 1, when improved sufficiently to remain upon his feet.

FIG. 1.—Steer 750 at noon.

FIG. 2.—Steer 750 at 12.01 p. m., showing its position after falling.

FIG. 3.—Steer 750 at 12.10 p. m., when moving unsteadily.

FIG. 4.—Steer 750 at 12.12 p. m.

FIG. 5.—Steer 750 at 12.14 p. m.

FIG. 6.—Steer 750 at 12.34 p. m.

FIG. 1.—Steer 750 at 12.35 p. m., after falling forward.

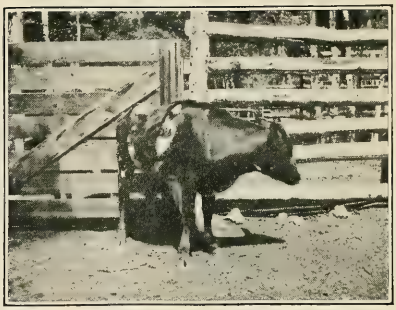

FIG. 2.—Steer 750 at 12.40 p. m., when upon its feet again.

FIG. 3.—Steer 750 at 12.43 p. m., when staggering.

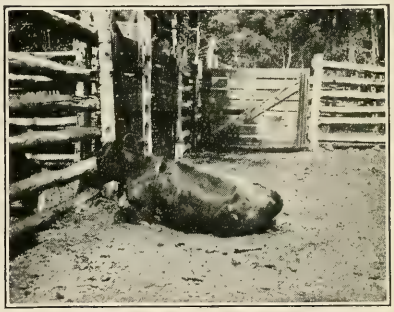

FIG. 4.—Steer 750 at 12.44 p. m., after falling.

FIG. 5.—Steer 750 at 12.50 p. m., dragging itself along after falling.

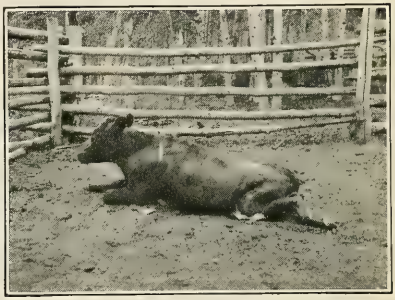

FIG. 6.—Steer 750 at 12.52 p. m.

the wall of the corral and fell. This was repeated two or three times, and it was noticed that before falling the head was drawn toward the body in somewhat the same attitude as that assumed by Horse 126. After 2 p. m. the steer was considered on the road to recovery and was able to remain upon its feet. It was kept in the corral until 5.30, August 28, when it was turned into the pasture. At that time, while it had recovered, it seemed somewhat weak and staggered when driven. Thereafter its recovery seemed to be complete.

On September 22, at 10.45 a. m., it was given 450 grams of dried plant, which was equivalent to 0.551 pound of green plant per hundredweight of animal. This animal was fed with about 5 pounds of alfalfa hay, and it was expected that this quantity might be sufficient to produce fatal results. By noon all but 2 pounds of the mixture had been eaten, and while no note was made of the completion of the feeding, it is supposed that the remainder was eaten during the afternoon.

At 7.15 a. m., September 23, the animal was found lying on the right side, and evidently had been lying and kicking for a considerable period. An unusual noise was heard in the corral that morning at 3.45 but was not investigated and it was presumed that the animal was down at that time. The pupils were dilated and the jaw moved constantly as if it were chewing. From that time until death, at 3.35 p. m., the animal was upon the ground most of the time and there were almost continuous spasms. It was considerably bloated and frequently breathed with groans. Considerable gas was belched from the stomach, which may have relieved the bloating to some extent. During the spasms the pupils were dilated and it was evident that the animal had salivated considerably.

Sometimes it bellowed loudly as though in pain and most of the time the spasms were so frequent that the motion of the legs was nearly continuous in a walking or running movement. In the spasms the head was sometimes drawn back in the position of opisthotonos, while at others it was drawn to the breast. This condition continued until death.

Immediately after death an autopsy was made. The body was considerably bloated, the gas being especially evident in the first and second stomachs. The blood vessels of the ileum were unusually full. The only other abnormal condition was the fullness of the blood vessels in the meninges of the brain and of the spinal cord.

SHEEP EXPERIMENTS.

Twenty-nine different experiments were made with sheep during the season of 1918. Of these 2 were sick and recovered and 10 died. Thirty-seven experiments with sheep were made in 1919. Of these 4 exhibited symptoms, 4 were sick, and 3 died. A general summary

of these cases is given in Table 1. In three of the experiments the plant, mixed with hay, was fed to the animals. In all other cases the feeding was by the balling gun, so that the animals received the material in a very short time. It does not seem necessary to give the details of all these cases, as they were very simple. Two cases that were fairly typical have been selected for an extended account.

Sheep 478.

This animal was an old ewe, in fair condition, weighing 100.5 pounds. On June 19 at 10.30 a. m. its temperature was 102.8° F., pulse 108, and respiration 39. Between 10.38 and 10.40 a. m. it was given, with the balling gun, for each hundredweight of animal, 0.165 pound of *Asclepias galioides* from Hotchkiss, Colo. The animal was kept under observation during that and succeeding days and showed no symptoms of poisoning. The highest temperature reached was 103.4° F., at 11 a. m. June 19. The animal, then weighing 114 pounds, was brought in August 19, 1918, for another experiment with the plant. At 10.03 a. m. its temperature was 102.1° F., its pulse 90, and respiration 48. At 11.09 it was given, for each hundredweight of animal, 0.11 pound of green *Asclepias galioides* which had been collected near High Rolls, N. Mex. There was no result from this feeding.

On August 28, when the animal weighed 111 pounds, another experiment was made. At 9.50 a. m. its temperature was 100.9° F., pulse 60, and respiration 36. At 11.35 a. m., for each hundredweight of animal it was given 0.138 pound of green plant of *Asclepias galioides* which had been collected near Paonia, Colo. From this feeding there was no result. On the next day, August 29, at 10.23 a. m., for each hundredweight of animal 0.138 pound of green plant of *Asclepias galioides* was given. This experiment, too, was without effect. On September 2 it was given 0.147 pound of green plant per hundredweight of animal, again without effect. On September 5 at 2.30 p. m. it received 0.167 pound of green plant per hundredweight of animal, the material having been collected near Paonia, Colo. The animal was kept under observation and no symptoms were noticed until 11.35 a. m. September 6. At that time it went down on its knees and lay stretched out upon the stomach. A subcutaneous injection of one-fourth grain of arecolin was given at 11.57. At 11.59 it was attempting to get up, but was unable to do so. The head was thrown back in the position of opisthotonos and then at times drawn to the breast. The respiration was labored.

Plate VII, figure 1, shows the attitude assumed by the animal at 11.57 and figure 2 at 11.58. Figure 2 is a characteristic attitude when the animal was kicking about, with its head thrown far back. At 12.02 p. m. the sheep was placed upon its feet but was unable to

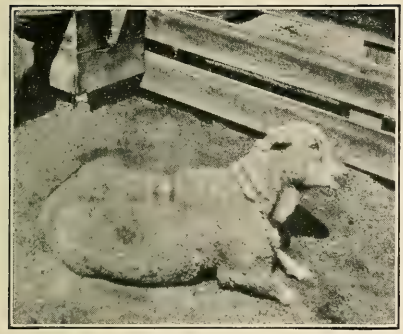

FIG. 1.—Sheep 478 at 11.57 a. m.

FIG. 2.—Sheep 478 at 11.58 a. m. A characteristic attitude when in a spasm.

FIG. 3.—Sheep 478 at 12.24 p. m., when attempting to rise.

FIG. 4.—Sheep 478 at 12.41 p. m., after falling forward.

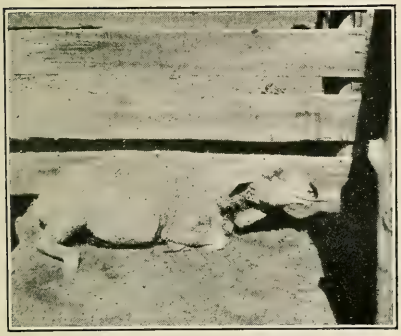

FIG. 5.—Sheep 478 at 12.45 p. m., in one of the intervals between spasms.

FIG. 6.—Sheep 478 at 1.05 p. m., when recovering.

stand. The respiration continued deep and labored. At 12.14 it got upon its feet, ran across the pen and fell down. This was repeated two or three times. At 12.25 it was able to stand for a few seconds, but fell forward again. At 12.31 it got up, fell twice, then got upon its feet and fell forward across the pen. Figure 3, taken at 12.24 p. m., shows its attitude when attempting to rise. Figure 4, taken at 12.41 p. m., shows the attitude as it fell forward in crossing the pen. Figure 5, taken at 12.45 p. m., shows the attitude when lying more quietly. At 12.45 p. m., it was given another dose of one-fourth grain of arecolin. In the spasms the eyes were dilated. and the head was either drawn to the breast or thrown far back. At 1 p. m. the animal seemed somewhat stronger, and it was taken out of the pen. It was then able to hold its head erect. Figure 6 shows the attitude assumed by the animal. After this the spasms were less frequent and it seemed to be gaining in strength. At 2.14 p. m. it was able to walk about 25 feet and a little later seemed to walk quite normally. It continued to gain in strength until about 4.40 p. m., when the condition seemed fairly normal. From that time it gained steadily.

The temperature was taken at intervals during this illness. At 6.35 p. m., September 5, it was 102.2° F., at 10.08 a. m., September 6, 100.2°, at 12.06 p. m., 103.7°, at 12.25, 104.4°, at 6.19 p. m., 103.3°, and the next morning, September 7, at 8.13 a. m., 100.9° F.

Sheep 476.

Sheep 476 was an old ewe, weighing 81.5 pounds at the time of experiment. On June 20 at 12.22 p. m. it was given 0.27 pound of *Asclepias galioides* per hundred pounds of animal. This was given by the balling gun, and the feeding was finished in about three minutes. The temperature at 2.20 p. m. was 101.9° F., pulse 102, and respiration 30. At 3.45 the temperature was 102.6°, pulse 150, and respiration 24. The respirations were deep and labored but regular. The sheep was down on its side with the head thrown back, and immediately went into a series of spasms. The legs were extended and stiff. At 3.55 p. m., while lying up its side, it was moving the legs as if running. The respiration was labored and the expiration forced. The heart was beating nearly 200 times a minute. The movements of the legs at times were slow and at other times very rapid. At 4.07 p. m. there was frothing at the mouth, bloating, and some gas was belched. These actions were repeated every 2 to 5 minutes during the afternoon. The bloating was very marked. At times the animal was trembling. In the spasms the head was drawn back and brought to the breast, and during that time the temperature went up to 105° F. The respira-

tion was never rapid and was labored during the full period. The spasms were repeated with very great frequency between 6.57 p. m. and 7.17 p. m. A record of the number of the spasms was taken and it was found that 59 occurred during the period. At 7.20 p. m. there was a violent spasm. The animal straightened out its legs, the heart stopped beating, and gas bubbled up through the throat and mouth.

In the autopsy upon this animal very little was noticed that was abnormal; in fact, this autopsy should hardly be considered typical. In the summarized account of the autopsies on page 28 is given a statement in regard to the general appearances of the internal organs of the animal after death.

CHEMICAL EXAMINATION.

No analysis of *Asclepias galioides* appears to have been made before this investigation and, although the present chemical examination has not been completed, it appears to be desirable to record the definite results already obtained.

The plant material used for the chemical work was taken from the same stock lots as that used in the feeding experiments and was consequently identical with it. Most of it was carefully dried and ground in a drug mill. One portion of green plant was, however, examined, but was found to contain nothing of a toxic nature which is not present also in the dried plant.

No attempt was made to determine all the constituents of the plant by a routine phytochemical analysis, since for this investigation, the substances responsible for range poisoning were alone important. On that account the chemical procedure was conducted primarily to yield knowledge of them.

A portion of the dried plant was extracted with petroleum ether and the extract was found to contain a large quantity of caoutchouc with coumarin and fatty matters. Several portions were exhausted with alcohol, which removed all the toxic substances. This extract was partly soluble in water and both the solution and the residue were toxic. The aqueous solution contained a very small quantity of a nontoxic alkaloidal substance corresponding to less than 0.01 per cent of the weight of the dry plant, two glucosids which may be separated from each other by their different solubility in chloroform, and sugars which appear to consist of maltose and a sugar which yields dextrosazone. Both of the glucosids are toxic and produce narcosis.

The water-insoluble portion of the alcohol extract contains fats, an orange-red coloring matter, a phytosterol, nontoxic resin acids, toxic glucosids which are probably identical with those found in

the water-soluble fraction, and the substance which causes the spasmodic symptoms observed in animals. After a complicated manipulation the last substance was obtained as a colorless, brittle, resinous mass which has not yet yielded anything of a crystalline nature. It melts indefinitely at about 60° C., is insoluble in water, aqueous acids, and alkalies, is very soluble in alcohol, amyl alcohol, glacial acetic acid, acetone, chloroform, ether, benzol, acetic ether, and pyridine. It does not appear to be glucosidal. Further investigation, with the object of determining its precise chemical nature, is in progress.

This substance has been thoroughly tested upon guinea pigs and produces the characteristic symptoms observed on the range, with the typical lesions.

Fresh samples of the plant were tested for the presence of volatile poisons and toxic saponins, with negative results.

PHARMACOLOGICAL RESULTS.

The pharmacological work was conducted according to the following plan: Each of the various fractions resulting from the chemical treatment of the plant extracts was administered through the mouth to an animal. Extracts which contained much matter insoluble in water were emulsified in that liquid with either acacia or mucilage of Irish moss; soluble extracts were given in water solution. Frequent control animals served to exclude accident.

The animals used were sheep and guinea pigs. The larger proportion of the testing was done with the latter animals, which were found to react excellently and characteristically to the toxins of the plant, duplicating the symptoms observed in the experimental sheep almost to the most minute detail. In indefinite cases the tests were repeated upon several animals; 126 experiments in all were conducted. As criteria in the work upon the guinea pigs were taken the symptoms and pathological lesions exhibited by the experimental sheep. By following this plan it was found possible to exclude many of the plant constituents as innocuous or as not factors in range poisoning and to locate definitely the fractions which contain toxic substances.

Three general and distinct types of intoxication were observed in guinea pigs which were drenched with toxic fractions of extracts from this plant.

The first type closely resembles the typical cases of range poisoning which follow the ingestion of the whole plant. This type of intoxication is produced by the resinous substance described above; it commences with a general weakness, the animal appears disinclined to move about, and is soon narcotized. After an interval convulsions appear, with the characteristic running movements in many cases and the peculiar tendency to fall and lie always on the same side of

the body. Clonic spasms, often with the typical drawing of the head to the thorax, are observed some time after the general convulsions have commenced. When resting between spasms the animal usually lies stretched out with the head in opisthotonos. All the animals which exhibited spasms eventually died. The autopsy showed, in general, heart in diastole with surface vessels full, lungs normal, liver, spleen, and kidneys usually normal, digestive tract normal, often containing much gas, central nervous system congested. This is similar to the typical picture in cases of range poisoning.

A second general type of cases is produced by the glucosid that was isolated from the water-soluble fraction of the alcohol extract by chloroform after making the solution alkaline. This type of case is not observed on the range because the quantity of the causative agent contained in a toxic dose of the plant is too small to assert itself over the spasmodic substance. Animals drenched with solutions of this glucosid are completely narcotized within a few minutes of the administration of the dose; they fall upon the side and are indifferent to stimuli. The respiration is deep and regular and the heart beat is normal. Animals remain in this condition for several hours and finally die with symptoms of respiratory paralysis. On autopsy these animals frequently show congestion of the digestive tract and of the central nervous system, but in some cases the brain and cord appeared normal.

The third general type of poisoning is produced by the glucosid which is not extracted from the aqueous solution of the alcoholic extract by chloroform. In these cases the animal shows no marked symptoms for several hours after the administration of the dose. Then there is evidence of weakness which continues, the animal loses weight rapidly, finally goes down upon the belly with the legs sprawled out, and dies in from 5 to 7 days after the drench. The autopsy in these cases does not furnish typical lesions; usually all the organs appear normal, but occasionally there is fullness in the central nervous system. Range cases do not show this type of intoxication for the same reason adduced in the case of the second type.

EXPERIMENTAL.

The following account of some typical experiments furnishes an indication of the general methods employed in the chemical investigation, leaving the more extended and detailed description for future publication.

Moisture, ash, and extract determination.—The material used for these determinations was dried *Asclepias galioides* collected in July, 1918, at Paonia, Colo., and reduced to a No. 60 powder.

	Per cent.
Moisture	6.22
Ash	11.38

Fifty grams were extracted in a Soxhlet apparatus with various solvents in succession:

	Grams.	Per cent.
Petroleum ether extracted	2.461	4.92
Benzol	1.293	2.58
Ether	0.274	0.54
Chloroform	0.636	1.27
Acetone	1.369	2.73
Alcohol	5.460	10.92
Total	-----	22.96

Each of these fractions was tested upon guinea pigs. The petroleum ether, acetone, and alcohol extracts were nontoxic; the benzol fraction produced the characteristic spasmodic type of intoxication observed on the range, and the autopsy exhibited the typical pathologic picture. The chloroform and ether extracts were toxic, producing narcosis.

Alkaloids.—Twenty-five grams of fresh plant were cut into small pieces and macerated for 24 hours in excess of 1 per cent hydrochloric acid. The yellowish extract, after filtration, reacted with the ordinary alkaloidal reagents, giving evidence of a minute quantity of basic substance. The base was not precipitated from its aqueous solutions by potassium hydroxid or ammonia.

Volatile poisons.—A total of 912 grams of the dried leaves and blossoms of *Asclepias galioides* collected at Paonia, Colo., in July, 1918, was mixed with 45 grams of barium hydroxid and 15 liters of water and allowed to stand overnight. The following morning the solution was tested and found to be alkaline to litmus. The mass was then distilled. This irregular procedure was necessary because the experiment was made in the field under conditions which did not permit of the most refined manipulation. There were obtained 2,400 mils of distillate, with an odor of tea. This was not alkaline and gave no pricipitate with Mayer's solution in the presence of hydrochloric acid. On standing, a minute quantity of oil collected on the surface. One thousand two hundred mils of this distillate, representing the volatile constituents of 456 grams of dried leaves and blossoms, were drenched into Sheep 491, weighing 130 pounds, without producing any effect.

Saponins.—Four hundred grams (about 20 toxic doses) of dried and ground Asclepias from Hotchkiss, Colo., were mixed with 4 liters of alcohol, allowed to stand 24 hours, and heated to boiling. The mass was maintained at the boiling temperature for an hour and then was filtered hot. The filtrate was a bright, full green. On cooling and standing, a small quantity of green waxy material separated, which was collected on a filter and washed with alcohol. It was insoluble in water and cold alcohol, was completely soluble in chloroform, and

gave no reaction with ferric chlorid. Two half-gram portions of it were suspended in water and drenched into a guinea pig without effect.

Alcohol extract.—Four thousand three hundred grams of the dried whole plant were extracted with alcohol, the solvent removed, and the residue treated with hot water, which dissolved a large quantity of it and left a resinous mass undissolved. Both the water solution and the residue were toxic; the solution produced a peculiar narcosis and the resin caused the characteristic spasmodic symptoms observed in range poisoning.

The resin.—This was divided into 4 fractions by treatment with petroleum ether, benzol, and alcohol in succession, when a small residue remained which was insoluble in the ordinary organic solvents, but dissolved in dilute sodium-carbonate solution and was nontoxic. The petroleum-ether fraction was nontoxic; the benzol fraction produced the spasmodic type of intoxication; the alcohol fraction was narcotic.

The aqueous solution.—A portion of this solution was investigated for the presence of toxic saponins, by treatment with barium hydroxid, and testing the various fractions obtained on guinea pigs. Nothing in the nature of a saponin was detected.

The main portion was made alkaline and extracted with chloroform. This treatment yielded a small quantity of a nontoxic alkaloid and a glucosidal substance which has strong narcotic properties. The aqueous liquid which remained after the chloroform extraction was still toxic, producing narcosis in experimental animals, and from it a second toxic glucosidal substance has been isolated.

The marc.—The marc remaining after the alcohol percolation was then extracted with boiling alcohol and this extract was kept separate from the first. The marc remaining after this treatment was thoroughly dried to free it from alcohol and tested for toxicity. On August 2, 1918, 43.5 grams of marc (60 grams of dried plant) were forced fed to Sheep 479, weight 93 pounds. This feeding produced no apparent effect, and on August 4 the same sheep received 87 grams of the dried marc, also without effect. On August 6 a further quantity of 174 grams of marc were forced fed to the same sheep, again without effect. On August 7, 269 grams of the marc were forced fed to Sheep 497, weight 81.5 pounds, and produced no effect. The marc evidently did not contain toxic matter responsible for the cases observed on the range.

SUMMARY OF CHEMICAL EXAMINATION.

The plant material used was identical with that employed in the feeding experiments. The fresh green plant and the dried plant were

examined and the fractions into which the extracts were divided were tested for pharmacological activity.

The investigation has yielded the following preliminary results: *Asclepias galioides* appears to contain several toxic compounds, some of which are glucosidal in nature. The substance which is responsible for the symptoms observed in range poisoning may be extracted from the plant with cold alcohol and is insoluble in hot or cold water. The plant yields water-soluble toxins, probably glucosids, which cause narcosis in experimental animals without congestion of the central nervous system.

In addition, the plant contains less than 0.01 per cent of an alkaloid which does not appear to be toxic and certainly does not influence the range cases. Attempts to discover toxic saponins in the plant were unsuccessful.

PART III.—GENERAL DISCUSSION AND CONCLUSIONS.

SYMPTOMS.

Generally speaking, the first evidence of intoxication is the loss of control of the muscles. The animal staggers when walking and eventually falls and is unable to rise. Sometimes it is found down before any other symptons appear. At this time there is, in most cases, salivation and there may be marked trembling.

The horse was in profuse perspiration. The loss of muscular control is most marked in the posterior part of the animal. The period during which the animal can remain upon its feet is generally very short. When down it generally makes strenuous efforts to rise but falls back with a good deal of violence. This feature was very marked in the case of the horse. It may be noted that in the range cases the animals are said to knock their heads on the ground. Soon there commences a series of clonic spasms. It is shown by the autopsies that the stomachs are greatly distended with gas, which is also true, to some extent, of the intestines. The formation of the gas continues during the period of intoxication, with some relief by belching and the spasms are correlated with the gas formation.

The bloat caused by the gas was one of the most noticeable features in the poisoned sheep. Vomiting occurred in one case, but was not a usual symptom. In the spasms the pupils are widely dilated. The spasms may become more or less tetanic in character. Ordinarily the animal throws itself repeatedly into a position of opisthotonos, as shown in Plate VII, figures 2 and 3, and this may be followed by a position close to emprosthotonos. Very characteristic is the position shown in Plate V, figures 1 and 4, in which the chin is brought down to the breast in a tetanic spasm. This was shown with especial clearness in Horse 126. Generally in this position the feet were drawn up to the body as shown in Plate V, figure 1. The spasms are some-

times very violent and apparently accompanied with a good deal of pain. When attempting to rise the animal repeatedly falls, and, because of the inability to raise its head from the ground frequently ruins the sight of the eye on the under side as its head is moved back and forth. It sometimes groans, and the respiration is commonly labored, with forced expiration. The pulse is rapid and weak, but the respiration is not much faster than normal; the spasms are frequently accompanied with convulsive movements of the jaw.

No series of temperatures were taken in the cases of the horse and steer. Several series were taken of the sheep and with fairly uniform results. Generally speaking there was a marked elevation in temperature soon after the first symptoms appeared. In some cases this high temperature appears for only a very short time, while in others,

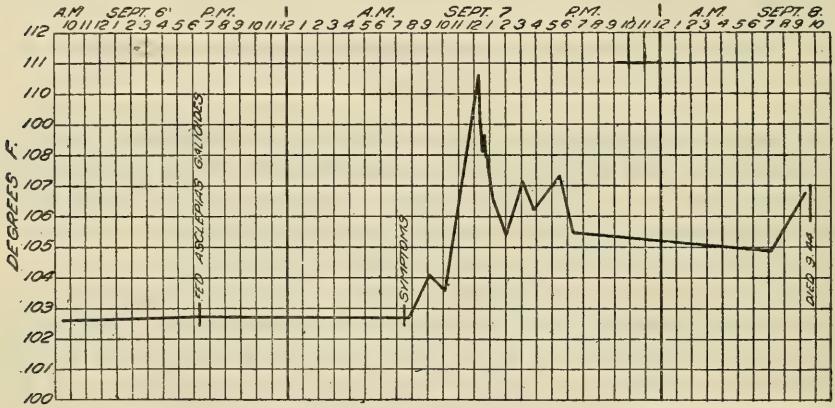

FIG. 2.—Temperature curve of Sheep 461.

as in Sheep 492, it continues for several hours. In all cases it becomes lower before death. Figure 2 shows the curve of temperature in Sheep 461, figure 3 in Sheep 483, and figure 4 in Sheep 492. In Sheep 461 it ran up to 110.6° F., the highest temperature observed. The increase in temperature, however, was not so marked in all cases. In Sheep 506 it reached only 103.4° F., but in the case of this animal it was distinctly an increase, and as the case continued during the night observations were dropped. A more complete set of observations might have shown more rise in temperature.

Glover, Newsom, and Robbins report the temperature of one of their experimental sheep in which a maximum of 110° F. was reached.

As the illness proceeds, in the intervals between the spasms, while lying upon its side, the animal moves its legs as though walking; these movements may become very rapid, as though the animal were running. These "running" movements are distinctly characteristic of the milkweed poisoning. There may be intervals of coma, but

more commonly the spasms continue until death. Generally the spasms occur at short intervals and there may be as many as 4 or 5 in a minute. They become somewhat reduced in intensity toward the end. Death comes from respiratory paralysis.

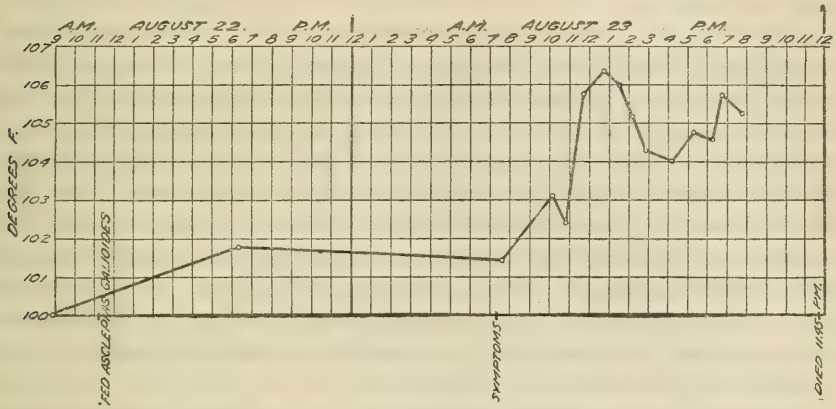

FIG. 3.—Temperature curve of Sheep 483.

The symptoms may be considered as falling into four more or less clearly marked stages:

1. A period of partial paralysis with staggering movements and falling.

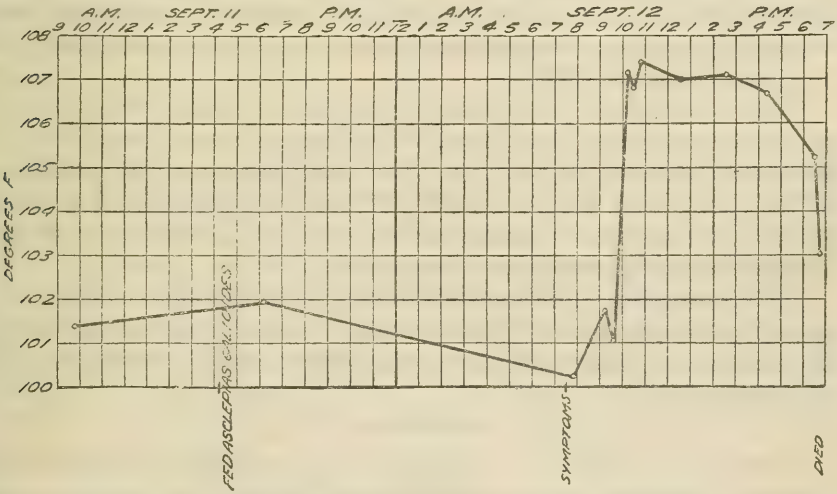

FIG. 4.—Temperature curve of Sheep 492.

2. A short period of violent spasms.

3. A period of spasms accompanied with running movements.

4. A period when spasms are of less intensity until death comes by respiratory paralysis.

AUTOPSY FINDINGS.

As noted in the description of symptoms, bloating is noticeable in practically all cases. This is found to be the result of the accumulation of gas not only in the first stomach, as is usual in most cases of bloating, but also in other parts of the alimentary canal. In the steer, No. 750, the gas occurred only in the first and second stomachs. Five of the 11 sheep autopsied had all 4 stomachs distended with gas. In one the gas was confined to the first and second stomachs and in 2 it was in the first, second, and fourth. In 3 there were no marked accumulations of gas in any of the stomachs, but the animals were bloated during their illness and the gas largely escaped either before death or soon after. In one case, 483, the gas was found in the duodenum, jejunum, ileum, and cecum, as well as in the stomachs. The distension of the cecum was noted in 6 cases. The presence of an abnormal quantity of gas in the alimentary canal may be considered as a condition always present in cases of poisoning by *Asclepias galioides*.

More or less congestion was found in the walls of the fourth stomach, duodenum, jejunum, ileum, and cecum. The colon was congested in only one case, No. 506, in which there was congestion in the second and third stomachs, as well as the fourth.

The lungs were congested in 5 of the 11 cases. The kidneys were generally congested, and in some cases congestion appeared in the thymus and thyroids. The bladder was commonly contracted and empty. Petechiæ or hemorrhagic spots occurred on the heart in some cases but not often.

There was usually congestion of the surface blood vessels of the brain and sometimes clots between the cerebrum and cerebellum, or in connection with the medulla. The blood vessels of the meninges of the spinal cord were unusually full, and in some cases clots were found in the cervical or lumbar region, or in both. The liver, so far as appeared in the autopsies, was normal.

The outstanding conditions which may be considered as characteristic of poisoning by this plant are the abnormal quantity of gas in the alimentary canal and the lesions in the kidneys and the central nervous system.

PATHOLOGY.

Microscopic study of the various tissues from animals poisoned by *Asclepias galioides* confirms the autopsy findings and shows some changes not noted in the macroscopic examinations. The results of the studies made on tissues from 9 sheep, 1 steer, and 1 guinea pig show the lesions to be very uniform in character.

The most prominent conditions found are marked capillary congestion and a cloudy swelling of certain tissue elements which modifies the appearance of congestion. The organs most noticeably

affected are kidney, lungs, heart, thyroid, thymus, and central nervous system, while minor changes are found in the liver, alimentary canal, and spleen. Thrombi occasionally occur in various organs.

KIDNEYS.

The lesions in the kidneys of the various animals differ some in detail, but in all there is pronounced albuminous degeneration of the epithelial cells lining the tubules, with marked swelling and disintegration of the cytoplasm. In places the swollen cells nearly fill the lumina of the tubules. Degenerative changes are most marked in the cells of the convoluted tubules, but may be largely due to their great bulk of cytoplasm. In certain instances the congestion is severe and general, but in most cases it is confined to relatively small areas. Greatly distended capillaries and veins occur, accompanied with considerable diapedesis and some edema. In such regions granules of blood pigment are abundant, showing that there has been a certain degree of destruction of red blood corpuscles. In some cases, many glomeruli are swollen, completely filling the capsule of Bowman, while others are edematous. Hemorrhages have occurred in a few glomeruli.

LUNGS.

Capillary congestion with diapedesis of erythrocytes and more or less severe transudation of serum into the alveoli is a quite characteristic condition in the lungs. In some cases there is a catarrhal condition of the bronchioles, with a marked exfoliation of the epithelium. In a few cases thrombi are found in some of the smaller veins.

HEART.

A study has been made of the wall of the left ventricle of the heart in the case of three sheep and one steer. The findings in these cases agree very closely. In the case of two sheep there is a very marked capillary congestion, with accompanying edema and some diapedesis of red corpuscles. In both these cases there is a mild degree of cloudy swelling, shown by the loss of cross striation and a somewhat granular cytoplasm. In the case of the steer and the other sheep the cloudy swelling has gone much farther. The muscle cells are markedly swollen and, except in certain restricted areas, the blood is squeezed out of the capillaries.

THYROID.

Samples of the thyroid gland were saved from 4 sheep, all of which showed pronounced capillary congestion.

THYMUS.

The thymus glands of 4 sheep and the steer were studied. All tissues of the glands of the sheep are very severely congested, the

interlobular connective tissue and the medullary portion of the lobules being more hemorrhagic than congested. The blood in these areas obscures the tissues of the gland. The thymus tissues of the steer are not congested, but have been invaded by numerous eosinophile leucocytes.

NERVOUS SYSTEM.

The following portions of the central nervous system have been studied—cerebral cortex, cerebellum, hippocampus, medulla, and cervical and lumbar cords. In all parts there is a fullness of the capillaries which in some cases, especially in the spinal cord, is congestion rather than fullness. The varying condition found is simply one of degree. The most marked pathological condition found is in the cervical spinal cord of Sheep 492. In these sections there is pronounced capillary congestion, especially of the gray matter, with areas where hemorrhages have occurred. The perivascular and pericellular lymph spaces are much distended, as is the central canal. This condition exists in most of the sections of the central nervous system examined which included tissues from 4 sheep and 1 guinea pig.

LIVER.

The only change characteristic of Asclepias poisoning noted in the liver is a slight though well-marked cloudy swelling of the hepatic cells.

ALIMENTARY CANAL.

In the abomasum and intestines of the sheep and the steer the changes as a rule are not severe. They are largely vascular and in most cases vary from fullness to mild congestion. Here the effects of the high capillary pressure are well shown in the unusually full and prominent capillaries in the muscular layers. These vascular changes are perhaps most marked in the ileum, but while of the same general character, in some instances a well-marked congestion, with edema and diapedesis of red blood cells, also exists in the mucosa. In the mucosa of the ileum of the steer there is besides the unusual number of red blood cells a very pronounced invasion of eosinophile cells. In some cases there is a marked excess of polymorphonuclear leucocytes in the mucosa.

SPLEEN.

Changes in the spleen were not so pronounced as in the tissues previously mentioned. They consisted of a possible distention of a few cavernous veins and a few small areas of congestion and sometimes the presence of considerable blood pigment. Guinea pig 35 was of interest, as many of the endothelial cells show their phagocytic function containing one or more red blood corpuscles and indicating a certain degree of blood destruction.

TOXIC AND LETHAL DOSES.

Two head of cattle were treated experimentally. In determining the dosage the milkweed was in all cases estimated as green material. It was found, by experiment, that in drying, the plant lost, on the average, about 70 per cent of its weight, and the dosage was figured out on this basis. The dosage was also estimated as applying to a 100-pound animal. As 100 pounds may be considered the average weight of a sheep and 1,000 pounds the weight of a horse or steer, the dosage applies to the average sheep, or multiplied by 10 to the average horse or steer.

Of the cattle, No. 815 received a maximum of 0.294 pound without effect. No. 750 received 0.626 pound without showing any symptoms of intoxication. On the following day it was given 0.845 pound and became very sick; in this case, however, there is reason to think that the full quantity given was not eaten. About a month after this experiment it was given 0.551 pound with a fatal result. Just why 0.551 pound produced death and 0.626 showed no effect is not evident, for as shown elsewhere (p. 34) it does not seem probable that repeated feedings either increase susceptibility or produce toleration. However, from these experiments it seems probable that the toxic and lethal doses for cattle are not far from one-half pound per 100 pounds of animal.

Three experiments were performed with a horse. Horse 126 was made very sick by 0.22 pound per 100 pounds of animal, and later received 0.14 pound without effect. In 1919 it was killed by 0.193 pound. This last feeding, however, was of leaves only, and these have been shown to be more poisonous than the other parts of the plant. About 0.2 pound per 100 pounds, then, may be considered the probable toxic and lethal dose for a horse.

The following table shows the dosage of sheep from which positive results were obtained:

TABLE 2.—*Quantities of milkweed fed to sheep, with positive results.*

Sheep.	Quantity fed.	Result.	Sheep.	Quantity fed.	Result.
1918.			1918.		
No.	*Pound.*		*No.*	*Pound.*	
478	0.167	Sickness.	509	0.22	Death.
506	.148	Do.	437	.168	Do.
468	.167	Death.	1919.		
475	.161	Do.	372	.206	Sickness.
476	.27	Do.	534	.191	Do.
480	.577	Do.	542	.198	Do.
483	.138	Do.	522	.147	Do.
492	.165	Do.	522	.198	Do.
506	.184	Do.	461	.22	Death.

The number of experimental cases of sheep was sufficiently large to make the figures on dosage fairly complete. There were 10 cases of

death and 7 of illness. Four animals were fed repeatedly, No. 509 three times, No. 506 five times, No. 478 six times, and No. 522 fourteen times, besides receiving feedings of marc three times.

It should be noted that Sheep No. 509 received the milkweed mixed with hay and ate it, so that the feeding was distributed over a number of hours—just how many was not determined. All the other sheep were fed by the balling gun, so that the material was received in a short time. There was, therefore, an opportunity for some elimination in the case of No. 509 and it may be expected that the effective dosage would be somewhat greater than in the other cases; this animal, after receiving smaller quantities in the preceding days, ate 0.22 pound per 100 pounds of animal between 11.10 a. m., June 22, and some time before 8.30 a. m. June 23.

Disregarding No. 509, however, and comparing only those sheep which were fed by the balling gun, the smallest quantity that caused symptoms was 0.148 pound with Sheep 506, and the largest quantity given without effect, except in those cases in which stems alone were fed, was to Sheep 522, 0.275 pound.

The smallest dose that produced death was 0.138 pound in the experiment with Sheep 483. It should be noticed that this lethal dose was somewhat smaller than the smallest toxic dose. An average of the fatal doses would not aid in determining the lethal dose, as an evident overdose was given in some cases, but 6 of the cases were killed by 0.184 pound or less.

From these cases it appears that the toxic dose is between 0.138 and 0.206 pound and that the lethal dose is from 0.138 to 0.22 pound. All these figures are computed on the basis of the green plant for a 100-pound animal.

It is evident that in *Asclepias galioides* we have an extremely toxic plant with very little difference between the toxic and lethal doses; No. 468 was killed by the same dose from which No. 478 recovered, and the smallest lethal dose is less than the smallest toxic dose in these experiments. The fact, too, that so many of the experimental cases died is evidence of the slight difference between the toxic and lethal dosage. The same thing is indicated in the high mortality of the range cases. The prognosis of poisoned cases is bad. In general, it may be stated that a dose of anything above 0.14 pound for a 100-pound sheep is liable to produce sickness or death.

Glover, Newsom, and Robbins give tentative figures for the dosage of 4 sheep, one of them dying on 63 grams, 0.139 pound, being practically the same as the minimum lethal dose of the authors of this paper. The weight of the sheep is not stated, however, and the plant was fed with consequent wastage and inaccuracy. In the Salina experiments all sheep were weighed and with one exception, Sheep 509, the plant was fed by the balling gun, so that the data were quite exact.

It must be remembered, too, that all these sheep were treated under corral conditions. It may be questioned whether the dosage would apply to sheep in pasture or on the range. Under the conditions which have existed in most recorded cases of poisoning, however, it is not probable that the dosage would have been much higher than in the experimental animals. In these reported cases, hungry animals have been more or less narrowly confined to areas on which the main vegetation was *Asclepias galioides*. Under such circumstances, as is well known, animals will eat large quantities in a very short time. Not only does their hunger make them eat rapidly and greedily, but jealousy of one another leads them to eat even more. It may be assumed then that grazing sheep may eat rapidly enough to make the dosage nearly or quite as small as in the case of the experimental animals. In comparing Sheep 509, which ate the plant, with grazing animals, it should be noted that range sheep do not eat so readily in corrals as on the range, and it is reasonable to suppose that a grazing sheep would be poisoned fully as quickly as a corral sheep.

SUSCEPTIBILITY OF DIFFERENT ANIMALS.

So far as the experiments show it appears that sheep and horses are about equally susceptible to poisoning from the plant. The method of feeding Sheep 509 and Horse 126 was the same, so that the two animals can be compared with each other. The lethal dose of the sheep was practically the same as the dose which produced violent illness in the horse. The dosage for Steer 750 was much greater, from which it seems probable that cattle are less susceptible than either sheep or horses. It does not follow, however, that horses are more liable to be poisoned than cattle, for horses are more particular about eating and there is less probability at any time of their eating any considerable quantity of injurious plants.

DELAY IN DEVELOPMENT OF SYMPTOMS.

The following table shows the time which elapsed after the plant was given before the symptoms appeared:

TABLE 3.—*Time elapsed between feeding of plant and development of symptoms.*

Animal.	Date and hour of feeding.	Date and hour of symptoms.	Time elapsed before symptoms.
1918.			*Hours.*
Horse 126	July 30, 3.35 p. m. to 5.15 p. m.	July 31, 7.45 a. m.	14
Steer 750	August 26, 12.05 p. m. to ——	August 27, 9.13 a. m.	21?
Steer 750	September 22, 10.45 a. m. to 12 noon	September 23, 3.45 a. m.	15¾
Sheep 468	September 7, 11.12 a. m.	September 8, dead 7.30 a. m.	20
Sheep 475	August 17, 12.28 p. m.	August 18, died 6.30 a. m.	18
Sheep 476	June 20, 12.22 p. m.	June 20, 3.45 p. m.	3

TABLE 3.—*Time elapsed between feeding of plant and development of symptoms*—Continued.

Animal.	Date and hour of feeding.	Date and hour of symptoms.	Time elapsed before symptoms.
1918.			*Hours.*
Sheep 478	September 5, 2.30 p. m.	September 6, 11.35 a. m.	21
Sheep 480	June 18, 2.58 p. m.	June 18, 5.15 p. m.	2¼
Sheep 483	August 22, 11.10 a. m.	August 23, 7.15 a. m.	20
Sheep 492	September 11, 4.10 p. m.	September 12, 7.50 a. m.	15
Sheep 506	September 11, 4.15 p. m.	September 12, 9.30 a. m.	17
Sheep 506	September 20, 5.05 p. m.	September 21, 3.18 p. m.	22
Sheep 509	June 22, 11.10 a. m. to (?)	June 23, 8.30 a. m.	21?
Sheep 437	September 16, 4.25 p. m.	September 17, 7.40 a. m.	15
1919.			
Sheep 372	September 10, 6 p. m.	September 11, 8.55 a. m.	15
Sheep 461	September 6, 6.15 p. m.	September 7, 7.30 a. m.	13½
Sheep 522	September 11, 6.55 p. m.	September 12, 8.40 a. m.	13¾
Sheep 522	September 22, 5.18 p. m.	September 23, 7.40 a. m.	14¼
Sheep 534	August 30, 6.30 p. m.	August 31, 7.40 a. m.	13¼
Sheep 542	September 3, 6.25 p. m.	September 4, 7.10 a. m.	12¾

It may be seen from the table that in 1918 it was about 14 hours after the horse had finished eating the plant before symptoms appeared.

In the feeding of the horse in 1919 it is not known when the feeding was completed, but apparently the symptoms of intoxication appeared in a shorter time.

Steer 750 was fed the first time about 12.05 p. m., and the first symptoms were noted about 9.13 a. m., the next day, a period of 21 hours. No note was made, however, of the time when the steer finished eating the plant, and it may be assumed that the period before evidence of intoxication was not more than 18 or 19 hours. At the second feeding there were symptoms in 15¾ hours after the feeding was finished.

In the case of sheep, information is lacking in regard to the incipience of symptoms in Nos. 468 and 475; it is not known when the feeding of No. 509 was completed. In regard to 14 sheep, however, notes were taken of the time when symptoms were first manifest. In these cases an average of the lapse of time between the feeding and the symptoms is 14.1 hours. The shortest time was 2¼ hours, in the case of No. 480, and the longest was 22 hours, in the case of No. 506. With the exception of Nos 476 and 480 all the cases lie between 15 and 22 hours.

One would naturally suppose that the larger doses would take effect in the shorter time, and an examination of the cases shows that this is true.

EFFECT OF REPEATED DOSES.

The repeated feedings which were given to several of the animals show significant results in regard to the questions of tolerance, in-

creased susceptibility, and accumulation. Following is a tabulation of repeated feedings:

TABLE 4.—*List of repeated feedings and results.*

Animal.	Date of feeding.	Quantity fed per 100 pounds of animal.	Result.	Animal.	Date of feeding.	Quantity fed per 100 pounds of animal.	Result.
	1918.	*Pound.*			1918.	*Pound.*	
Steer 750	Aug. 22	0.22	Not sick.	Sheep 470	July 6	0.0473	Not sick.
	Aug. 25	.626	Do.	Sheep 470	July 7	.0473	Do.
	Aug. 26	.845	Very sick.	Sheep 470	July 8	.0473	Do.
	Sept. 22	.551	Death.	Sheep 470	July 9	.05	Do.
Horse 126	July 30	.22	Very sick.	Sheep 470	July 10	.05	Do.
	Sept. 20	.140	Not sick.	Sheep 470	July 11	.05	Do.
Sheep 478	June 19	.165	Do.	Sheep 470	July 12	.05	Do.
	Aug. 19	.110	Do.	Sheep 470	July 13	.05	Do.
	Aug. 28	.138	Do.	Sheep 470	July 14	.05	Do.
	Aug. 29	.138	Do.		1919.		
	Sept. 2	.147	Do.				
	Sept. 5	.167	Sick.	Sheep 522	Aug. 11	.142	Do.
Sheep 506	Aug. 26	.132	Not sick.	Sheep 522	Aug 14	.155	Do.
	Sept. 11	.148	Symptoms.	Sheep 522	Aug. 16	.162	Do.
	Sept. 12	.151	Not sick.	Sheep 522	Aug. 18	.169	Do.
	Sept. 16	.160	Do.	Sheep 522	Aug. 20	.176	Do.
	Sept. 18	.172	Do.	Sheep 522	Aug. 23	.183	Do.
	Sept. 20	.184	Death.	Sheep 522	Aug. 25	.191	Do.
Sheep 509	June 20	.189	Not sick.	Sheep 522	Aug. 27	.198	Do.
	June 21	.22(ate 0.2)	Do.	Sheep 522	Aug. 29	.204	Do.
	June 22	.22(ate 0.24)	Death.	Sheep 522	Sept. 1	.219	Do.
Sheep 470	July 2	.0473	Not sick.	Sheep 522	Sept. 6	.247	Do.
Sheep 470	July 3	.0473	Do.	Sheep 522	Sept. 9	.275	Do.
Sheep 470	July 4	.0558	Do.	Sheep 522	Sept. 11	.198	Symptoms.
Sheep 470	July 5	.055	Do.	Sheep 522	Sept. 22	.147	Sick.

Sheep 470, from July 2 to July 14, was fed a daily ration of from 0.05 to 0.0558 pound, receiving in the whole period a total of 0.6473 pound, with no resulting ill effects.

So far as cumulative effect is concerned, the 5 sheep and Steer 750 are the only animals that would have any bearing on the question. Sheep 470 received in 15 days about four times the toxic dose with no effect. Sheep 478, in addition to the feedings of June 19 and August 19, received on August 28 and 29 and September 2 doses equal to that which proved fatal for No. 483, yet on September 5 it was poisoned by an average dose, which was practically like that given on June 19 with no result.

In the case of Sheep 506, which on September 11 showed symptoms from 0.148 pound, slightly increased doses on September 12, 16, and 18 produced no results, and death was caused on September 20 by 0.184 pound.

Sheep 509, which was not affected by 0.2 pound on June 21, was killed the next day by 0.24 pound, which is probably close to the toxic or lethal dose for the plant as eaten by a sheep.

Sheep 522, besides having received three feedings of marc, was given 14 feedings between August 11 and September 22 of quantities varying from 0.142 pound to 0.275 pound. All the feedings except the last were of material from Palisades, Colo., which, as shown elsewhere (p. 37), was less toxic than that from other localities. On September 22 it was made sick by 0.147 pound of leaves from Rockville, Utah.

Steer 750, after a small feeding on August 22, received August 25 0.626 pound without effect, was poisoned on August 26 by an undetermined quantity, and killed September 22 by 0.551 pound.

In none of these cases is there any clear evidence that *Asclepias galioides* should be considered a cumulative poison. Neither did the fact that an animal had been poisoned once increase its susceptibility to the effect of the poison. It is doubtful, too, whether we are justified in thinking that any marked degree of tolerance is acquired by repeated feeding. Sheep 478 was not affected June 19 by 0.165 pound, but after repeated doses, ranging from 0.11 to 0.147 pound, was made sick on September 5 by 0.167 pound. Sheep 506 was given repeated doses with small increases until it was killed on September 20 by 0.184 pound, having shown symptoms on September 11 from 0.148 pound. This sheep, taken by itself, may possibly be considered as having acquired some tolerance, yet the difference between the fatal dose, 0.182 pound, and the toxic dose September 11 of 0.148 pound, is not great, and in the case of Sheep 478 the difference between 0.165 pound, which produced no results, and 0.167 pound, which produced symptoms, is negligible.

In the case of Steer 750 evidently no tolerance was acquired.

The experience with Sheep 522 may be considered as conclusive evidence that neither is the plant a cumulative poison, nor is any tolerance acquired by repeated feedings.

SEASONAL VARIATIONS IN TOXICITY.

The material from Hotchkiss, Colo., used in the experiments, consisted of young plants in bud. That obtained from Paonia, Colo., Rockville, Utah, and High Rolls, N. Mex., was in flower, while that obtained from Grand Junction, Colo., and Palisades, Colo., was in flower and fruit. The number of experiments was not sufficient to show definitely whether there is a variation in toxicity at different seasons or not, but so far as the work went the plant appears to be uniformly toxic at all ages.

No experiments were made with the plant cured and dried standing, but the numerous accounts of the loss of sheep when feeding upon the plant in this condition make it reasonably certain that it retains more or less of its toxicity. It follows that losses may occur at any time when the plant can be obtained and that hay containing any considerable quantity is dangerous.

RELATIVE TOXICITY OF LEAVES AND STEMS.

In the experiments of 1918 the whole plant was used. Inasmuch as it was desirable to know whether all parts of the plant were equally toxic, a number of experiments of feeding leaves only and stems only were made in 1919.

There were eleven feedings of stems of material collected at Palisades, Colo., the quantity fed varying from 0.147 pound to 0.404 pound. None of these feedings produced any effect, while one feeding of leaves, Sheep 461, 0.22 pound, caused death, and four feedings, Sheep 534, 0.191 pound, Sheep 542, 0.198 pound, Sheep 372, 0.206 pound, and Sheep 522, 0.198 pound produced toxic effect. Of the material collected at Rockville, Utah, three feedings of stems in quantities from 0.367 pound to 0.477 pound produced no effect, while Sheep 522 was made sick on 0.147 pound of leaves.

It is not to be inferred that the stems possess no toxic properties, but it seems very clear that the leaves are vastly more poisonous.

LOCAL VARIATIONS IN TOXICITY.

In the work of 1919, material was used from three localities, Paonia and Palisades, Colo., and Rockville, Utah. The Paonia material was used only in connection with the chemical work, either an extract or the marc being given. The Paonia collections had been used in 1918, however, showing that as small a quantity as 0.138 pound might produce death. The High Rolls material produced death on 0.16 pound. The relative toxicity of the Palisades and Rockville material was brought out quite clearly in the experiments of 1919. With the Palisades material death was produced in one case, Sheep 461 with 0.22 pound, while symptoms were caused by quantities varying from 0.191 pound to 0.206 pound. With the Rockville material Sheep 522 showed symptoms on 0.147 pound, while the horse was killed by 0.161 pound. That is, to produce intoxication, it took about a third more of the Palisades material than of that collected at Rockville. In this connection it should be noted that Sheep 548 received 0.176 pound of leaves from Palisades without effect.

While the Paonia, High Rolls, and Rockville materials were about equally toxic, the Palisades plants were much less so.

These differences in toxicity can not be explained by any seasonal change, and apparently are a local peculiarity.

REMEDIES.

Two animals, Sheep 437 and Sheep 506, were treated with atropin and morphin. The latter produced some effect in controlling the violence of the convulsions, but both sheep died and it did not appear that the remedy affected the final result.

On the theory that free action of the bowels might give relief, Horse 126 was treated with subcutaneous injections of arecolin and recovered. The same remedy was used with Sheep 478, Sheep 492, and Steer 750. Sheep 478 recovered, while Sheep 492 and Steer 750 died.

On the basis of the same theory, Sheep 372 and Sheep 461 were treated with eserin and pilocarpin. In both cases the eserin produced defecation. Sheep 372 recovered, while Sheep 461, which received a somewhat larger dosage, died. It is evident that the results from the use of arecolin and eserin were somewhat doubtful. While it seems probable that the course of the illness was somewhat modified, these drugs can hardly be considered as effective remedies.

From the character of the lesions in the central nervous system it seems probable that no remedy would be very effectual, and that little reliance should be placed on any kind of treatment. Possibly if a line of symptomatic treatment were followed with the same care with which a human patient is treated, the course of the illness might be modified, but such treatment is impracticable, and in any case a fatal result is to be expected in most animals.

ERADICATION OF THE WHORLED MILKWEED.

The apparent rapid increase of this weed in some sections, together with the fact that it is dangerous in hay as well as while green, makes the question of its eradication an exceedingly important one.

From what has been said of the habits of the plant, it is evident that its eradication will be a very difficult matter, for the young seedling, once started in a favorable location, begins to spread by adventitious buds from roots, being greatly aided by cultivation where cover crops are not grown. The rapid spread of the plant is aided by ordinary cultivation. The more the plant is broken, the better it thrives. Disk harrowing and plowing, without removal of the roots, simply helps to propagate the plant.

If the roots are exposed on the surface they will die, but every piece left in the ground becomes the possible origin of a new plant, and the greater the number of pieces, the larger will be the resulting crop. Plate IV, figure 2, shows a plant growing from a piece of root one-quarter of an inch long.

Presumably if tilled crops like beets, potatoes, and corn are grown, intensive cultivation by destroying the aerial parts of the plant will eventually have some effect, but it is a discouraging piece of work.

Cutting or mowing the milkweed before seeding, while it does not eliminate the plant, will accomplish much in preventing its distribution. This is especially important in driveways where hungry animals are trailed, and in locations like bedding grounds, where animals are herded close together. Had this been done in the "death patch" near Cortez, previously referred to, the losses would have been greatly reduced, if not entirely avoided.

Prevention of seeding of the whorled milkweed will stop the spread of the plant to a considerable extent. Mowing milkweed and de-

stroying it, wherever it is common on range or trail, will solve the poison danger for the season, often saving thousands of dollars. Where the milkweed is growing in a meadow it should be carefully culled out by hand, for hay containing any considerable quantity of it is deadly to animals that eat it, and the hay therefore is worthless for feeding purposes.

PREVENTION BY CARE OF STOCK.

While it is not true that animals instinctively avoid injurious plants, it is true that they seldom eat them by choice. In the case of the whorled milkweed they seem to have an actual dislike of the plant, and eat it only when forced by hunger. This can be seen in many small pastures in western Colorado where whorled milkweed is abundant but forage is also plentiful, and the animals avoid the milkweed. Poisoning occurs when animals are confined in a pasture with little else to eat, when they are driven in a more or less hungry condition along trails where there is milkweed, or when they are on overgrazed ranges. It is evident that if the herder recognizes the dangerous character of the plant and uses suitable care, most losses will be avoided.

Care also should be taken, if hay from a milkweed region is used, to see that it contains no considerable quantity of the weed. If the weed is mature, as is generally the case, it is readily recognized by the pods.

SUMMARY.

The whorled milkweed growing in Colorado, Utah, New Mexico, and Arizona has been proved to be exceedingly poisonous.

The weed has been identified botanically as *Asclepias galioides*. In previous publications it has been cited as *Asclepias verticillata*.

The plant is poisonous to horses, cattle, and sheep, but most of the reported losses have been of sheep.

The most marked symptoms are the violent spasms. The autopsies and microscopical examinations show congestion of the peripheral blood vessels, the congestion being especially marked in some glands, the lungs, and the central nervous system.

The chemical examination of the plant, while incomplete, has demonstrated the existence of definite toxic compounds, part of which are glucosidal in nature. The plant contains also a minute quantity of nontoxic alkaloid.

There is no medicinal remedy which gives satisfactory results. Reliance must be placed on the destruction of the plant and such care of stock as will prevent hungry animals from coming into contact with masses of the weed.

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Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

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WATERFOWL AND THEIR FOOD PLANTS IN THE SANDHILL REGION OF NEBRASKA,

Part I. WATERFOWL IN NEBRASKA

By HARRY C. OBERHOLSER, Assistant Biologist

Part II. WILD-DUCK FOODS OF THE SANDHILL REGION OF NEBRASKA

By W. L. McATEE, Assistant Biologist

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WM. A. TAYLOR, Chief

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By

DAVID GRIFFITHS, Agriculturist, Office of Horticultural and Pomological Investigations, and H. E. JUENEMANN, Superintendent of the Bellingham Plant-Introduction Field Station Office of Foreign Seed and Plant Introduction

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PREPARED UNDER THE DIRECTION OF WM. WALLACE MEIN
ASSISTANT TO THE SECRETARY IN CHARGE OF
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