" The first farmer was the first man, and all historic nobility rests on possession and use of land."

—EMERSON.

LIPPINCOTT'S COLLEGE TEXTS

AGRICULTURE

EDITED BY

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THE POTATO

ITS CULTURE, USES, HISTORY AND CLASSIFICATION

BY WILLIAM STUART

HORTICULTURIST, U. S. DEPARTMENT OF AGRICULTURE

ACRES OF FLOWERS GREET THE EYE IN NORTHERN MAINE THE LATTER PART OF JULY

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ILLUSTRATIONS IN THE TEXT

"If vain our toil,
We ought to blame the culture, not the soil."
Pope—*Essay on Man*

PHILADELPHIA AND LONDON
J. B. LIPPINCOTT COMPANY

PRINTED BY J. B. LIPPINCOTT COMPANY
AT THE WASHINGTON SQUARE PRESS
PHILADELPHIA, U. S. A.

DEDICATED TO MY DEPARTED FRIEND AND COUNSELLOR CYRUS GUERNSEY PRINGLE WHOSE EARLY YEARS WERE DEVOTED TO THE BREEDING OF SUPERIOR CEREALS, VEGETABLES, AND FRUITS.

PREFACE

The great importance of the potato as a human food in all countries having temperate climates is now more fully appreciated than ever before. The rôle that this crop played in the late "World War," especially in Germany and Austria, may never be fully realized outside of these two countries themselves. Naturally, a crop of such great economic importance as the potato, and one having such a wide adaptation to the soil and climatic conditions, involves many cultural problems and has many enemies in the shape of insect and fungous pests with which to contend. The grower of this crop, therefore, has to be continually on the alert to protect the crop from injury by either insects or disease, and at the same time to give the plants good cultural care. Each year, it would seem, brings new problems for the scientists to solve. It is little wonder, therefore, that much has been written upon the potato since it was first introduced into Europe from South America.

In the preparation of this book, it has been the aim of the author to discuss the basic principles underlying the production of potatoes, as well as to include the latest available information in regard to the industry as a whole. No one appreciates more keenly than does the writer how difficult it is to completely cover all phases of the subject. The best that can be hoped for is that it will approach the ideal desired.

No effort has been made to discuss potato production methods in foreign countries, and little is given concerning the varieties grown there. The author's actual observations and field studies, extending over many years and many states, are used in making the treatment of each topic more practical and complete.

In the potato project outline, given in the Appendix, operations and studies are given in seasonal sequence, for the benefit of the students and young farmers who plan to grow, for the first time, a crop of potatoes for profit.

The author desires to express his very great obligation to the United States Department of Agriculture for a large share of the photographs used for illustrative purposes; to many kind friends, some of whom have reviewed certain chapters of the book, and others who have contributed information or material in the form of photographs or literature. To attempt to enumerate the names of all these would be difficult, and possibly dangerous in that some of them might be overlooked.

William Stuart.

Washington, D. C.
1923.

CONTENTS

THE POTATO

CHAPTER I

THE POTATO AS A WORLD CROP AND ITS RELATIVE IMPORTANCE IN THE UNITED STATES

Relative Magnitude.—A careful consideration of the relative magnitude of the potato as a world crop, reveals the fact that, from the production standpoint, it far exceeds that of any other table food plant. The statistical data, presented in the following table, includes the production of potatoes, oats, corn, wheat, rye, and barley. The production of rice is purposely omitted, owing to incomplete data; but there is every reason to believe that if complete statistical information were available, the world's rice crop insofar as volume of production is concerned, would probably be a close competitor of wheat. Owing to the World War it has not been possible to secure reliable statistical data regarding the extent of the crops produced by Germany and her allies since 1913, hence the data presented represents the average for the years 1909 to 1913 inclusive.

A careful analysis of these data shows that the potato crop far exceeds that of the cereal crops.

Comparison of the average world production of potatoes, oats, corn, wheat, rye, and barley with that of the United States for the years 1909 *to* 1913 *inclusive**

Crop	World's crop in bushels	Per cent. of total	United States crop in bushels	Per cent. by United States
Potatoes.	5,453,419,000	26.52	354,095,600	6.49
Oats	4,323,736,000	21.02	1,131,219,400	26.16
Corn	3,807,036,000	18.51	2,752,371,600	72.30
Wheat ..	3,725,551,400	18.12	697,459,000	18.45
Rye.....	1,788,286,600	8.70	35,460,000	1.98
Barley ..	1,467,505,000	7.13	181,273,800	12.35

*From data given in the 1915 Yearbook U. S. D. A.

This excess is over one billion bushels above that of oats; one and one-half billion bushels over that of corn, and nearly one and three-quarter billion bushels greater than that of wheat. The rye and barley crops are less than one-third that of potatoes.

A somewhat clearer comprehension of the relative magnitude of these six crops is obtained from the graphic chart (Fig. 1).

In order to study the relative magnitude of these crops in the United States as compared with the world's production, these data are also presented in the preceding table, with the percentage of each crop produced in this country.

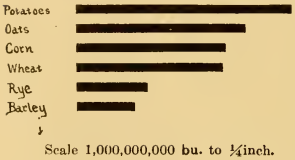


FIG. 1.—World production of food crops 1909-1913.

A study of these data shows extremely wide variations in the magnitude of production and percentage. For example, while this country produces only about 2 per cent of the world's crop of rye, over 72 per cent of the corn crop is grown in the United States. The percentage of the other crops given are as follows: oats 26.16; wheat 18.72; barley, 12.35; while in the case of potatoes the crop of the United States is only 6.49 per cent of the world's crop.

Home *vs* Foreign Potato Production.—It is of considerable interest in the present study of the potato crop, to compare the production of the United States with that of some of the leading foreign potato-producing countries, in order to study in greater detail the relative position of each with respect to volume of production. These data, which are assembled in the next table, are rather illuminating in that they show the magnitude of the crop produced in Germany and Russia, and the relatively small crop grown in the United States. It will also be noted, that while this country occupies fifth position both in acreage and volume of production, yet it is next to the lowest in acre yield. The data further shows that the potato crop of Germany is almost five times greater than that of the United States for the years mentioned, or, expressed in percentage, our crop is but 21 per cent of the German crop. A study of the percentage of the world's crop of potatoes, produced by the countries included in the following table, discloses equally interesting comparisons.

Germany's crop represents 30.8 per cent of the total production; Russia's 22.9; Austria Hungary 12.1; France 8.9; United States 6.5; Great Britain 4.6; Belgium and the Netherlands each about 2 per cent. Another very interesting comparison may be made from these data relative to the average production per acre.

Average acreage grown and bushels produced in the leading potato growing countries of Europe and America, 1909–1913 *inclusive* †

Country	(a) Area in acres	Total bushels	(b) Average bushels per acre	(b) Percentage of World's Crop
Germany	8,260,250	1,681,959,000	203.6	30.8
Russia (European)	11,127,250	1,251,425,600	112.5	22.9
Austria Hungary	4,888,250	662,202,400	135.5	12.1
France	3,841,000	489,376,800	127.4	9.0
United States	3,679,500	354,095,600	96.2	6.5
Great Britain	1,169,250	254,438,200	217.6	4.7
Netherlands	414,500	110,152,600	265.7	2.0
Belgium	389,667(2)	107,021,000	274.6	2.0
Spain	715,000(3)	92,051,500	128.7	1.7
Italy	657,500	60,813,400	92.5	1.1
Canada	475,750	77,872,400	163.7	1.4
Sweden	379,000	63,759,200	168.2	1.2
So. America (1)	301,000	48,238,800	160.3	0.9
Switzerland	185,667(4)	40,537,400	218.3	0.7
Denmark	139,667(5)	32,440,400	232.3	0.6

† No later European data available.
(a) Average 1911-1913.
(b) Computed from columns 1 and 2.
(1) Argentina and Chile.
(2) 1911, 1912 and 1913 data.
(3) 1910 and 1912 data.
(4) 1911, 1912, and 1913 data.
(5) 1910, 1911, and 1912 data.
Note. All data in columns 1 and 2 from the Yearbook of the U. S. D. A.

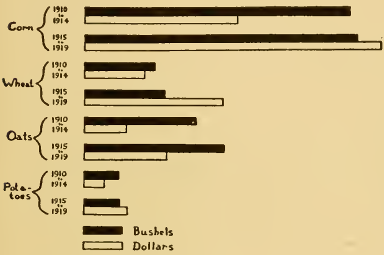
Ranked on this basis, Belgium leads the list with an average of 274.6 bushels; the Netherlands come next with 265.7; Denmark is third with 232.3 bushels per acre; Switzerland is fourth with 218.3; Great Britain fifth with 217.6, and Germany sixth with 203.6 bushels. The nine remaining countries rank as follows: Sweden 168.2; Canada 163.7; South America 160.3; Austria Hungary 135.5; Spain 128.7; France 127.4; Russia 112.5; United States 96.2; and Italy 92.5.

Relative Importance of the Potato Crop in the United States.—As determined by acreage and value of the crop produced, the potato occupies sixth place among the crops grown in the United States. If, however, it is considered on the basis of a table

Average acreage, production, and farm value of corn, hay, wheat, cotton, oats, and potatoes grown in the United States during the five-year periods 1910-1914 *and* 1915-1919.

Crop	Years	Average acreage	Average acre yield	Average annual production	Ave. annual value of crop Dec. 1	Average annual acre value	Per cent increase over 1910-1914 period
Corn.........	1910-1914	105,239,600	25.9 bu.	2,732,457,200 bu.	$1,576,938,200	$ 13.31	
	1915-1919	106,953,000	26.3 "	2,809,413,600 "	3,054,822,200	28.56	114.6
Hay.........	1910-1914	49,376,800	1.34 tons	66,234,400 tons	812,003,600	16.44	
	1915-1919	54,827,000	1.56 "	85,681,200 "	1,348,760,200	24.60	49.6
Wheat.......	1910-1914	48,952,600	14.8 bu.	728,224,600 bu.	629,639,200	12.86	
	1915-1919	58,059,600	14.3 "	832,239,800 "	1,429,243,400	24.62	91.4
Cotton.......	1910-1914	35,330,400	192.1 lbs.	14,259,200 bales	727,418,800	20.59	
	1915-1919	33,918,000	160.9 "	11,402,800 "	1,390,145,800	40.98	99.5
Oats.........	1910-1914	38,013,800	30.5 bu.	1,157,960,800 bu.	442,909,400	11.65	
	1915-1919	42,565,000	33.7 "	1,436,008,200 "	852,566,600	20.03	71.9
Potatoes.....	1910-1914	3,685,800	97.8 "	36,772,400 "	213,651,400	57.9	
	1915-1919	3,998,200	92.5 "	371,708,600 "	450,641,400	112.71	97.4

food product, it undoubtedly is only second to that of wheat. The data, as presented in the table (p. 4) show the average annual acreage, production, and farm value of these six leading agricultural crops in the United States for the two five-year periods of 1910-1914, and 1915-1919. It is clearly evident from these data that the corn crop is, by all odds, the most important. Its total value is greater than hay and wheat combined, and is some seven times more valuable than the potato crop. In production per acre potatoes easily take the lead, both in bushels and in money value. In comparing the money value of a crop, it is very necessary to take into consideration the actual cost of producing it. For example, the cost of producing a crop of wheat or oats is necessarily less than that of corn; and, to a much greater extent, this is true in a comparison of the production costs of corn and potatoes. The potato crop is a much more expensive one to grow. This increased cost is self-evident to those familiar with potato production. It may be briefly summed up in two words, labor and fertilizer. These two items are the big factors in the growing of potatoes in sections where commercial fertilizers are used.



Scale ¼ inch 400,000,000 bu. or dollars.

FIG. 2.—Average production in bushels and farm value in dollars Dec. 1, for 1910-1914, 1915-1919.

The data in the table illustrates one other point quite as forcibly as that of relative yield and farm values; it is that of the upward trend of prices of agricultural products during the last five-year period. To the writer, this is one of the most striking lessons presented in the table. With very little variation in acre yields, the value of the crops have, in some cases, more than doubled. Corn, for example, increased over 114 per cent; hay nearly 50 per cent; wheat over 91; cotton almost 100; oats nearly 72, and potatoes over 97 per cent.

It is thus apparent that war conditions enhanced the value of agricultural products quite materially.

The main object in presenting these data is, however, primarily for the purpose of comparing the relative importance of the potato crop in American agriculture in such a way as to permit of quick comparison with that of the grain crops, corn, wheat, and oats. This is well illustrated in figure 2 which graphically represents the production and value of the corn, wheat, oats, and potato crops during the two five-year periods 1910 to 1914 and 1915 to 1919 (Fig. 2).

QUESTIONS ON THE TEXT

1. What is the relative magnitude of the potato when viewed as a world crop?
2. With what other food crops is it compared?
3. Why has the rice crop been omitted?
4. What is the relative importance of rice as compared with wheat?
5. What percentage of the total of these six food crops consists of potatoes?
6. What crop is next in percentage of production to the potato?
7. Give order of next four crops.
8. What is the excess production of potatoes over corn and wheat?
9. What percentage of the world's potato crop does the United States produce?
10. What percentage of the world's corn crop does the United States produce?
11. What is the respective magnitude of the other four crops as expressed in percentages?
12. What position does the United States occupy with other countries as regards the magnitude of her potato crop?
13. What countries exceed the United States in potato production?
14. Name the six leading countries in the order of their importance from the standpoint of production?
15. Give the percentage that each of these six countries produce.
16. What country produces the largest average yield per acre?
17. Give the six leading countries based on acreage production.
18. What position does the United States occupy in yield per acre?
19. What is the relative importance, based on money value, of the potato crop in the United States, as compared with corn, hay, wheat, cotton and oats?

QUESTIONS SUGGESTED BY THE TEXT

1. What is the annual yield of potatoes in your county and state?
2. Compare the yields of potatoes and six other important crops in your county and state?

CHAPTER II

POTATO PRODUCTION IN NORTH AMERICA

United States Production.—While it has been shown in the preceding chapter that the potato crop of the United States is hardly more than a drop in the bucket, as it were, of the world's crop, it is, nevertheless, a very important agricultural crop in certain sections of the United States and Canada. Owing to rather unreliable and fragmentary data concerning potato production in Mexico, no attempt has been made to include it in the present discussion. The data presented in the tables on pages 8 and 9 give the average acreage and production for two five-year periods, 1912-1916, and 1915-1919, inclusive. The main object in presenting these two sets of data is that of affording an opportunity to observe the changes brought about in some sections, as a result of war conditions, in the acreage devoted to potato production. One of the interesting features of these changes is that of the rank or relative position of the various states with respect to the magnitude of their production. A study of the table shows that only three of the six largest producing states maintained their relative positions during the two five-year periods. These states were New York, Wisconsin, and Pennsylvania. Michigan drops from second to fourth place, Maine from fourth to fifth, while Minnesota passes from fifth to second position. In the second group of six states the position of every one is slightly changed; for example, Virginia moves into seventh place and Ohio drops from seventh to ninth; while California rises from eleventh to eighth position, and Iowa drops from ninth to fourteenth place. While these changes in rank are interesting to note, they are by no means vital to the industry, except as they illustrate responses to economic or climatic conditions, the first of which reacts in a larger or smaller acreage according as to whether the previous crop brought a high or a low price; and the second, in the production of a larger or smaller number of bushels per given area, as is evidenced by a comparison of the average yield per acre. The climatic factor exerts a much greater influence on the total production of any given section than does the ordinary fluctuation in acreage, due to economic conditions. There are, of course, exceptions to the preceding statement, as was evidenced by the very large increase in the 1918 acreage in a number of the Southern states, particularly in Florida, due to the exceedingly high price received for the 1917 crop.

Average acreage and production of potatoes by States for the years 1912-1916, inclusive

Rank	State	Number of acres	Number of bushels	Average bushels per acre
1	New York	352,400	32,485,000	91
2	Michigan	347,800	30,139,800	86
3	Wisconsin	295,600	28,865,400	97
4	Maine	133,600	28,560,800	212
5	Minnesota	271,000	28,223,000	105
6	Pennsylvania	270,000	23,909,000	89
7	Ohio	157,800	12,833,600	80
8	Virginia	115,400	11,833,300	100
9	Iowa	141,200	11,247,600	78
10	New Jersey	91,200	10,252,400	113
11	California	74,800	9,859,400	132
12	Illinois	127,400	9,627,400	75
13	Washington	61,600	8,884,600	144
14	Nebraska	113,800	8,751,800	77
15	Colorado	63,600	7,466,000	121
16	Oregon	53,400	7,069,600	130
17	North Dakota	67,400	6,712,200	101
18	Indiana	77,200	6,054,800	77
19	Missouri	89,600	5,881,000	65
20	South Dakota	63,600	5,794,000	91
21	Montana	37,600	5,449,000	145
22	Idaho	31,600	5,015,000	157
23	Kansas	71,200	4,797,400	68
24	West Virginia	48,200	4,382,800	91
25	Kentucky	50,200	4,078,600	81
26	Maryland	42,200	3,934,000	94
27	Vermont	24,600	3,236,600	131
28	Utah	19,800	3,203,000	162
29	Massachusetts	26,200	3,159,000	120
30	Tennessee	36,600	2,680,000	73
31	North Carolina	32,400	2,609,200	80
32	Texas	44,600	2,606,000	58
33	Connecticut	23,400	2,479,800	106
34	Oklahoma	32,400	2,135,400	66
35	New Hampshire	16,400	2,095,400	127
36	Nevada	12,400	2,076,400	166
37	Wyoming	14,600	1,946,000	134
38	Arkansas	25,600	1,839,000	71
39	Louisiana	24,400	1,588,600	66
40	Alabama	18,200	1,509,800	83
41	Florida	12,600	1,009,000	81
42	Delaware	10,800	976,400	90
43	Mississippi	11,800	952,000	81
44	Georgia	13,600	925,600	69
45	South Carolina	10,400	820,000	79
46	New Mexico	8,600	805,600	94
47	Rhode Island	5,000	592,000	118
48	Arizona	1,000	104,000	104
	Averages and totals	3,674,800	361,450,200	98.2

Average acreage and production of potatoes by States for the years 1915-1919, inclusive

Rank	State	Number of acres	Number of bushels	Average bushels per acre
1	New York	363,600	31,843,400	87.6
2	Minnesota	295,400	27,894,000	94.4
3	Wisconsin	299,800	27,238,000	90.9
4	Michigan	343,800	25,892,000	75.3
5	Maine	126,200	23,309,600	184.7
6	Pennsylvania	280,400	23,226,000	82.8
7	Virginia	139,200	15,052,000	108.1
8	California	87,200	12,032,400	137.9
9	Ohio	152,600	11,037,200	72.3
10	New Jersey	100,600	10,991,200	109.2
11	Illinois	143,200	10,838,000	75.7
12	Colorado	74,800	10,747,000	143.7
13	Nebraska	119,600	9,688,200	81.0
14	Iowa	123,200	8,940,200	72.5
15	Washington	64,200	8,715,200	135.8
16	Missouri	102,800	7,793,400	75.8
17	North Dakota	85,400	6,564,600	76.9
18	South Dakota	79,600	6,491,000	81.5
19	Indiana	89,800	6,377,000	71.0
20	Oregon	54,600	6,320,000	115.8
21	Kentucky	63,400	5,585,400	88.1
22	West Virginia	53,000	5,262,800	99.3
23	Montana	46,400	5,181,000	111.7
24	Idaho	32,800	5,064,800	154.4
25	Kansas	73,400	4,943,400	67.3
26	Maryland	51,000	4,752,600	93.2
27	North Carolina	48,400	4,397,000	90.8
28	Tennessee	44,400	3,525,600	79.4
29	Massachusetts	31,200	3,451,400	110.6
30	Wyoming	26,000	3,398,000	130.7
31	Utah	20,000	3,288,800	164.4
32	Vermont	26,000	2,986,600	114.9
33	Alabama	37,000	2,934,400	79.3
34	Texas	48,000	2,917,200	60.8
35	Arkansas	37,600	2,709,200	72.1
36	Oklahoma	39,800	2,496,200	62.7
37	Connecticut	24,400	2,279,000	93.4
38	New Hampshire	18,800	2,202,400	117.2
39	Louisiana	31,600	2,119,600	67.1
40	Florida	22,200	1,933,800	87.1
41	Nevada	10,600	1,922,400	181.4
42	South Carolina	19,200	1,740,200	90.6
43	Georgia	19,200	1,351,200	70.4
44	Mississippi	15,600	1,250,000	80.4
45	Delaware	11,400	1,027,400	90.1
46	New Mexico	9,600	877,400	91.4
47	Rhode Island	5,000	534,000	106.8
48	Arizona	3,200	281,000	87.8
	Averages and totals	3,995,200	371,403,200	92.9

A detailed study of the annual acreage, production, average yield per acre, and price per bushel of potatoes by states during the years 1915-1919, (see table in Appendix) shows that, with but few exceptions, the acreage increase in 1917 was quite marked in the North, due to the high prices received for the 1916 crop; whereas, in the South the greatest increase in acreage occurred in 1918, following, as has been previously mentioned, the high prices received for the Southern 1917 crop. If we neglect the years 1917 and 1918 and study the acreage of the three previous years, it will be noted that there is comparatively little fluctuation in the total acreage planted. On the other hand, it is at once apparent from the data presented that there is comparatively little relation between acreage and yield. This statement can, perhaps, be best illustrated by noting the variation in yield between Iowa's 1915 and 1916 crops, in which the acreage variation is less than 5 per cent., while that of the yield is nearly 160 per cent. Further evidence of fluctuating variations in yield may be noted by a comparison of the New York, Michigan, and Wisconsin data, in which the variation in acreage between the years 1915 and 1919 in New York was less than 2.3 per cent, while the variation in yield was nearly 80 per cent. The Michigan data show the widest variation in yield between the years 1916 and 1917 in which the acreage fluctuation was a little over 1.8 per cent while the yield variation was nearly 134 per cent. In Wisconsin, the variation in 1916 and 1917 potato acreage was a little less than 6 per cent, while the increase in yield was nearly 157 per cent.

The chief interest in these data lies not so much in the magnitude of production of each state, as it does in the average yield per acre. This, it would seem, is a better indication of the relative adaptability and economic value of a crop, than is that of its magnitude of production in any given state. Considered on this basis, Maine leads with 187.1 bushels per acre; Nevada, second, with 183.1; Utah, third, with 164.4; and Idaho fourth, with 154.1 bushels. In each of these states except the first, most of the potatoes are grown on irrigated land. The lowest yielding states are those of Texas, Oklahoma, Louisiana, Kansas, and Georgia. In most of these states, potatoes are grown largely for the early market; consequently they are usually harvested before they have attained their full growth, and in consequence thereof, do not give the yields that they otherwise would if allowed to reach full maturity.

Potato Production in Canada.—While the production of potatoes in Canada has not assumed the magnitude of that of the United States as judged in terms of bushels, it more than compares favorably with it, if the comparison is made on the basis of population. On such a basis, the 1918 Canadian crop of 105,579,000 bushels would call for a production by the United States of about 1,302,141,000 or nearly four times as much as is now being grown. It will be seen, therefore, that much depends upon the kind of comparison that one attempts to make, as to whether a crop seems relatively small or relatively large. All of the nine provinces which constitute the Dominion of Canada produce considerable quantities of potatoes as compared with their population. For the purpose of comparison, the acreage, production and average price per bushel for the years 1912 to 1918 have been tabulated (see Appendix). A study of this data shows quite a variation in yields from year to year which, for the most part, are attributable to unfavorable or favorable climatic influences.

Total Production and Yield per Acre by Provinces.—A further study of the data shows that they stand in production in the following order, the total average production being given:

Quebec	21,076,571 bushels,	144.5 bush. per acre.
Ontario	18,352,286 bushels,	120.1 bush. per acre.
New Brunswick	8,278,514 bushels,	186.2 bush. per acre.
Nova Scotia	7,255,786 bushels,	199.7 bush. per acre.
Saskatchewan	6,211,843 bushels,	154.3 bush. per acre.
Prince Edward Island	5,885,329 bushels,	182.7 bush. per acre.
Manitoba	4,893,556 bushels,	159.6 bush. per acre.
Alberta	4,891,914 bushels,	157.9 bush. per acre.
British Columbia	3,221,857 bushels,	207.6 bush. per acre.

The data on the production of Canada for the years 1912 to 1918, as shown in the table, indicate the same variation in yields as in the United States, with the additional feature of a very large increase both in acreage and production in 1918.

Acreage and Yields by Years.—The next table shows the results arranged by years from 1912 to 1918 inclusive. *

A Summary of the data relative to production indicates that the total average yield for the United States and Canada, exclusive of Newfoundland, for the past five seasons, 1914 to 1918 inclusive, is 459,169,740 bushels. If we add to this about one and one-half million bushels from Newfoundland and a million bushels from Mexico, it makes the average total production of North America

* Data taken from Canada Census and Statistic monthly.

approximately 461,669,740 bushels or a little over one-fourth that of Germany. If, on the other hand, we regard the last two seasons' crops as more nearly indicative of what can be marketed advantageously in the North American continent, we need to add about fifty million more bushels to the figures previously submitted, making a grand total of over 510 and one-half million bushels.

Total acreage and production of potatoes in Canada for the years 1912-1918

Year	Acreage	Total Yield bus.	Av. bus. per acre.	Av. price per bus.
1912	484,000	84,885,000	175.4	$0.44
1913	473,500	78,544,000	165.9	.49
1914	475,900	85,672,000	180.0	.49
1915	479,000	62,604,000	130.8	.57
1916	473,000	63,297,000	136.2	.81
1917	656,958	79,892,000	121.5	1.01
1918	735,192	105,579,700	143.5	.98
Average	539,650	80,067,671	150.5	.684

One of the most significant features of potato production in the United States is that, during the past five seasons 1915-1919, the 21 Northern States produced over two-thirds (68.8 per cent) of the total crop, the remaining third being about equally divided between the 11 Far West States and the 16 Southern States.

United States	Crop, 370,493,800 bushels.
21 Northern States	258,006,200 bushels, 68.8 per cent.
11 Far West States	56,238,200 bushels, 15.2 per cent.
16 Southern States	56,249,400 bushels, 16.0 per cent.

As larger areas in the far west states are brought under irrigation, increased potato production may be expected, but the bulk of the crop must, of necessity, be produced within a reasonable distance of the consuming public.

QUESTIONS ON THE TEXT

1. Of what importance is the potato as an agricultural crop in North America?
2. According to the data presented, what states lead in potato production?
3. Does the second period of five years show any material change in the relative rank of the leading states?
4. What two factors influence potato production in any given section?
5. Which of the two factors is the greater?
6. What lessons are to be derived from the average yields per acre for the different states?
7. Name some of the highest yielding states?

8. Name some of the lowest yielding ones?
9. How does the Canadian crop compare in per capita production with that of the United States?
10. Which of the nine Canadian provinces shows the largest average acre production?
11. How does the acreage production of the provinces compare with that of individual states in the United States?
12. What is the approximate extent of the North American potato crop?
13. How does it compare with that of Germany?
14. What percentage of the potato crop of the United States do the 21 Northern States produce?
15. How much do the 11 Western States produce?
16. How much do the 16 Southern States produce?
17. What limits a large expansion of potato production in the West?

QUESTIONS SUGGESTED BY THE TEXT

1. Have the yields and acreages in your state been increasing or decreasing?
2. Give the probable factors influencing this.
3. Are the yields per acre in your state changing materially? If so, why?
4. Compare the yields of potatoes in your state with six other food crops of the state.
5. Compare the potato production in your state with other states nearest to it in rank.

CHAPTER III

LEADING ENVIRONMENTAL INFLUENCES IN POTATO CULTURE.—SOIL, TEMPERATURE, AND MOISTURE

The three leading environmental influences which are most closely associated with the production of a profitable crop of potatoes are those of soil, temperature, and moisture. These factors, while not so completely under the control of the grower as those of plant food, tillage, and spraying, are, nevertheless, under intelligent management capable of a considerable degree of modification.

The first requisite on the part of the grower in the profitable production of any crop is a thorough understanding of its requirements in the way of soil, temperature, and moisture. It is necessary to know whether it is a heat or a cold, a moisture or a drought loving plant, and the character of soil best suited to its development. In the case of the potato, it is well known that it is a cool loving plant; that it requires a reasonable supply of moisture for its best development, and that, while more or less cosmopolitan in its soil requirements, it nevertheless thrives best on sandy, gravelly, or shaly loam soils.

The successful production of potatoes may then be said to be confined to regions in which the mean temperature during the growing season is relatively low; where the normal rainfall during the same period is sufficient to insure a steady growth of the plants, or where the land can be irrigated and where the soil is of such a character as to provide the most suitable conditions for the development of both plants and tubers. To a certain extent, therefore, these requirements confine the production of the late potatoes, at least, to the northern portions of the United States.

Soil Requirements.—While the potato plant is rather cosmopolitan in its soil requirements, it nevertheless succeeds much better on certain types of soils than on others. Generally speaking, sandy, gravelly or shaly loam soils are conceded to be the best, while a heavy sticky clay, or a very light sandy soil is admittedly the poorest and should always be avoided when possible. Potatoes may be successfully grown on muck or peat soils, and in certain sections of the United States quite a potato industry has been developed on these types of soil. As a rule, however, potatoes produced on muck or peat soils are less rich in starch than those grown on a gravelly or sandy loam soil. To be entirely suited to the potato crop a soil must be loose and friable, well supplied with organic matter, deep, well drained and with sufficient moisture, either from natural or artificial sources, to insure the development of a good crop. Furthermore, as is shown in the discussion of temperature, soil which is naturally cool is the more desirable for potato culture. The type of soil known as the Caribou loam, which is found in Aroostook County, Maine, is almost ideal in this respect. This is a chocolate brown colored soil, abundantly supplied with small decomposing fragments of shale rock with which it is underlaid. This shale formation, which generally lies in a vertical or partially horizontal position, is more or less regularly seamed, affording almost perfect drainage through its crevices, while during dry weather it serves as a source of moisture supply to the soil above it.

The question of soil moisture is not such a vital one in the irrigated regions of the West, as is the question of drainage and suitability of the physical texture and composition of the soil to the potato plant and to irrigation.

Land Elevation.—The elevation of the land may and does very materially influence its desirability. The choice of similarly located lands with respect to shipping facilities should always be made in favor of that having the greatest altitude, provided such altitude is not sufficient to preclude the successful growth of the potato. For example in the New England States, an elevation of 2000 to 2500 feet is equal to one of 6000 or 7000 feet in the West, so far as seasonal and climatic conditions are concerned, and this must, of necessity, be taken into consideration in the selection of a potato farm.

Temperature Conditions.—In view of the fact that temperature plays a very important rôle in potato production, and that it is a factor over which the grower can exercise very little control, it is essential that the temperature conditions of any given locality should be very carefully studied before engaging very extensively in the growing of this crop. In this connection, Smith[5] says:

"In the United States the potato has made its greatest development in the cooler sections of the country, where the mean annual temperature is between 40 and 50 degrees F. and where the mean temperature in July is not over 70 degrees. Further, the greatest yields of potatoes per acre are in those states where the mean annual temperature is below 45, and where the mean of the warmest month is not far from 65."

He further assumes the thermal constant of the potato to be 43 degrees F. and that the sum of the average daily degrees of heat above 43 represents the effective growing temperature for this crop necessary to bring it to maturity.

In Ohio, Smith found that while cool weather is more favorable to tuber production than warm, in each month considered, the temperature of either May, June, August, September, or October alone, has very slight influence as compared with July upon the

Fig. 3.—Environmental influence on form of tuber of Green Mountain. Tubers 1, 2, 5, and 6, very much modified; 3 and 4 true to type. Modification due to heat and drouth. Tubers produced from the same strain of seed.

potato yield. Also that the temperature of June, and July, July and August, or June, July and August combined had just about the same effect as that for July alone. It is believed that Smith's statement should be qualified by a further one, in which it is clearly set forth that if the potato crop is planted in Ohio approximately at a given date, the critical temperature period in the growth of the plants, so far as its influence upon yield is concerned, is during the month of July. The critical temperature period in the growth of the potato plant, insofar as it exercises a distinctly favorable or unfavorable influence on yield, is during the time in which it is developing its tubers. In regions in which the growing season is sufficiently long so that the planting date may vary from four to six or more weeks, it is quite possible, with a thorough knowledge of the average normal temperature conditions that may be expected in each growing month, to so govern the time of planting as to subject the plants to the most unfavorable temperature conditions at the period in their growth when the least injury would be incurred. For example, in Western New York it is customary to delay the planting of the late crop of potatoes until the early part of June, and sometimes even to July 1. This practice is, in all probability, not the direct result of any careful study of the temperature conditions prevailing in any given month, but due rather to the fact that the later planting usually gave better yields. A four years' experience in growing potatoes near Rochester, New York, inclines the writer to believe that August, rather than July,

Fig. 4.—Environmental influence on form of tuber of Irish Cobbler. Tubers 1 and 2 very much modified, 3 and 4 true to type. Modification due to heat and drought. Sources of seed identical.

is the critical month in that section; August rather than July being the critical month simply from the fact that the crop is planted later, and is setting its tubers during this period. Were the crop planted a month earlier, July would doubtless represent the critical period. There can be no question but that high air and soil temperatures are incompatible with a healthy and normal growth of the potato plant; and if extremely high temperatures prevail when the plants should normally set and develop their tubers, the yield will be materially reduced and the tubers visibly modified (Figs. 3-6). For this reason, the chief potato producing regions of the United States must, of necessity, be confined to the northern and north-eastern tier of states. In the South where the potato is, in some sections, grown extensively as an early truck crop, early planting provides temperature conditions which in the main are comparable with those of the North. In this connection Smith says (p. 224) "that whether the date of planting is February in northern Georgia, or May 1 in the northern portion of the United States, the seasonal rise has brought the temperature close to 45 degrees F."

It should be clearly borne in mind that while the amount of injury sustained by the potato plant is, as has been said, very largely dependent on whether it occurs during the critical period in the development of the plant, there is another element which may very materially increase or minimize high temperature injury

Fig. 5.—Environmental influence on form of tuber of Carman No. 3 Tubers 1 and 2 very much modified, 3 and 4 true to type. Modification due to heat and drought. Source of seed identical.

to the crop, and that is the presence or absence of a sufficient amount of moisture in the soil. If high temperatures are accompanied by a low soil moisture content during the critical period in the life of the plant, and these conditions prevail for any considerable period, the injury sustained will be very much greater than when a sufficient amount of soil moisture is present. In the first place, high temperatures accompanied by a drought usually result in a large amount of what the physiologist recognizes as tip-burn of the foliage, brought about through a more rapid transpiration of moisture through the leaves of the potato plant than its roots can supply, owing to lack of available moisture in the soil. As a result of this unbalanced ratio between moisture loss and moisture supply, the cells of the tips and margins of the growing leaves soon collapse and dry up, giving the plant the appearance of having been scorched by fire. This type of injury may occur prior to the formation of tubers, but is far more likely to occur during or after their formation.

The presence of a sufficient amount of soil moisture exercises a favorable influence on the soil temperature during protracted heat periods, by reason of the cooling effect exerted through the evaporation of moisture from both the soil and the plants growing thereon.

Soil temperatures are believed to play a by no means

Fig. 6.—Environmental influence on form of tuber of Rural New Yorker No. 2. Tubers 1 and 2 very much modified, 3 and 4 true to type. Modification due to heat and drouth. Source of seed identical.

unimportant rôle in the determination of potato yields. Of course, it must be conceded that high soil temperatures cannot obtain except when a high air temperature prevails. In some greenhouse studies recently made by Fitch[3] the effect of temperature and moisture upon the health and vigor of potato plants was noted. The soil temperatures employed were 50, 65, 80, and 90 degrees F., and the moisture content of the soil approximately 10 to 20 per cent for all the period; 20 per cent for 75 days, then 30 for 5 days; and 40 for the fourth lot, which, however, the author says, he did not dare to use during the main growing period, believing that it would cripple the plants. Potatoes maintained at 95 degrees F. were all killed before coming up.

In regard to the relation of temperature to moisture Fitch found a distinct correlation, that is, the higher the temperature and the moisture the greater the amount of injury to the plant. Plants grown in soil having an approximate moisture content of 10 per cent did not show any bad effects from being subjected to 80 degrees F.

Moisture.—The important rôle that water plays in the growth of both plants and animals has long been recognized and has very justly received a great deal of attention. Several years ago Arthur [1] read a paper before the members of the American Carnation Society, entitled "Moisture, the Plant's Greatest Requirement" in which the following statements were made (p. 67):

> "If we remember that the chief growth of the plant takes place in the parts where the largest amount of water occurs, we shall be reasonably safe in inferring that 'water is a very essential factor in growth. It has been ascertained, in fact, that the tissues must not only be saturated with water, but they must be super-saturated, that is, contain so much water that every cell is distended with the pressure, before growth will proceed."

It is well known that the food elements in the soil necessary to the proper development of the plant must first be brought into solution by the soil moisture before they can be taken up by the delicate root-hairs of the plant. Furthermore, it is known that water is, also, just as essential in transporting the liquefied food elements from root to leaf, and the elaborated food from the leaves to other parts of the plant. Hence it is that every metabolic process of the plant is concerned with moisture. At the same time, it must be remembered that while an abundance of water is desirable, an over-abundance may be, and usually is, harmful.

Moisture Requirements.—The actual amount of water necessary to the development of one pound of dry matter in the growing plant has been rather carefully studied by the plant physicist. King[4] of Wisconsin, found that it required from 301 to 576 pounds of water to produce one pound of dried potato. Briggs and Shantz[2] found that it required, under semi-arid conditions in Colorado, 636 pounds of water to produce one pound of dry matter. Widtsoe[6] in a somewhat different manner ascertained that, under irrigation conditions as they obtain in Utah, the evapo-transpiration ratio between moisture and dry matter varied in direct proportion to the number of acre inches of water applied to the crop. When 5 acre inches were applied, the ratio was 1 to 1136; while with 60 acre inches it was 1 to 3292.

Usually measurements of water required to produce one pound of dry matter are based upon the amount of water actually transpired by the leaves and stems of the plant and do not therefore represent the moisture loss due to evaporation from the soil itself Smith says, (*l.c.* p. 225):

"This water requirement is sometimes called the 'transpiration ratio' ......It does not take into account the water from a rainfall that may run off from the surface of the ground or what is lost by seepage or surface evaporation."

Widtsoe's data takes both of these factors into consideration.

Rainfall.—In determining the suitability of any given region for potato production on the basis of annual rainfall it is highly essential that careful consideration should be given to the distribution of the season's rainfall. The average precipitation during the growing season is the real determining factor. In the best potato growing regions the average total rainfall, during the period between planting and harvesting late potatoes, varies from 12 to nearly 18 inches. But, even where the heavier precipitation occurs, it might be so unevenly distributed as to make it impossible to produce heavy yields. A goodly supply of moisture is essential to a quick and healthy growth of the plant, and, when the tubers are set, to promote a steady and uniform growth. Heavy precipitations during the latter part of the growing season are not desirable, as they favor the development of late blight and rot, and also make it difficult to harvest the crop in a satisfactory condition. Much may be done by the grower to conserve the soil moisture by good cultivation and the maintaining of an earth mulch. This subject will be more fully discussed under tillage.

QUESTIONS ON THE TEXT

1. What are the three leading environmental factors in potato culture?
2. To what extent are these three factors controllable by man?
3. To what regions is the successful production of potatoes usually confined?
4. What are the soil requirements for potatoes?
5. Describe the Caribou loam soil.
6. Of what importance is land elevation?
7. What does Smith say about temperature influence?
8. According to Smith, which is the most critical period in the life of the potato plant so far as tuber production is concerned?
9. If any, what qualification would you make?
10. What happens to the potato plant when high air and soil temperatures are accompanied by a low soil moisture content?
11. Explain physiological collapse of cell structure of the leaf?
12. What effect has high soil temperature on tuber production? Cite Fitch's experiments.
13. Of what importance is moisture to the plant?
14. Give Arthur's statement regarding cell saturation and cell growth.
15. What amount of water did King, Briggs, Shantz, and Widtsoe find was necessary to produce a pound of dry matter?
16. In determining the suitability of any given region to potato production based on its rainfall, what factors should be considered?

QUESTIONS SUGGESTED BY THE TEXT

1. To what extent is the soil of your region considered suitable for potato growing?
2. What bad effects of summer heat are noticed by your local growers?
3. In what months, if any, is the local rainfall likely to be deficient?
4. Find specimens, if possible, showing results similar to those shown in the figures of this chapter.

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CHAPTER IV

THE SOIL AND ITS PREPARATION FOR THE CROP

In the preceding chapter the question of soil was discussed, as an environmental factor exercising a more or less direct influence on the character of the potato crop produced. In the present chapter it is proposed to study the soil from the standpoint of its proper preparation for the crop. It is well known that while the potato is probably as cosmopolitan in its soil requirements as almost any other agricultural crop, it nevertheless thrives best on certain types of loam soil, as for example sandy, gravelly or shaly loam soils. Maximum crops cannot be expected from very light sandy, or heavy clay soils. Neither can maximum crops

Fig. 7.—Plowing a clover sod with a tractor turning two furrows 14 inches in width and 9 and 10 inches in depth. Aroostook Co., Me., Aug., 1917.

be obtained from poorly drained soils, or from those deficient in organic matter, or in plant food. Hence all these points should be carefully studied before selecting the soil on which the crop is to be grown.

Organic Matter.—The importance of an abundant supply of organic matter in the soil can hardly be over-emphasized. A goodly supply of organic matter not only permits of keeping the land in a much more friable condition, but guarantees, as it were, a continuous supply of available plant food. In view of the relative importance of organic matter, or humus, as it is commonly called, in the soil, it is always desirable to grow potatoes on a clover or alfalfa sod whenever it is possible to do so. In the South the cowpea, velvet bean or the soybean may serve the same purpose, and be a more acceptable plant to grow in the crop rotation. As rotation crops are discussed in another chapter it is unnecessary to further consider this matter except that it concerns the plowing under of the rowen in the fall in the case of clover in the North, or of the last cutting of alfalfa in alfalfa-growing districts or of cowpeas, velvet beans, or soybeans in the South.

Plowing and Fitting the Land.—It is generally desirable to plow the land intended for the potato crop in the fall, except in

FIG. 8.—Plowing a clover sod with a pair of horses.

the case of soil that is apt to wash badly during the winter rains and snows. The plowing of the land varies somewhat according to whether the previous crop was alfalfa or clover.

Alfalfa Sod.—The usual practice in handling an alfalfa sod is to crown it early in the autumn. The process of crowning consists in plowing the sod as lightly as possible, three to four inches is sufficient, and allowing it to lie exposed to the sun, rain, snow and frost during the winter months. The object of early crowning of the sod is to furnish favorable conditions for the drying up of the crowns of the plants. This process is materially aided by repeated disking of the crowned land in the autumn. In the spring, this land should be plowed to a depth of from 9 to 10 or more inches. The above method for preparing alfalfa land for a potato crop is the one most generally practised, but there are a few growers who prefer spring plowing, after the alfalfa has attained a height of from 8 to 12 inches. When this practice is followed, only one plowing is made and this one as deep as it is possible to do conveniently.

Clover Sod.—It is the general custom, where a clover sod is to be turned under, to plow the land in the fall. At this time it is

Fig. 9.—The use of the plank drag is the final step in the preparation of the potato seed bed. Where the ground is a little cloddy or the surface somewhat uneven, the grower will be well repaid for the extra labor involved. (Courtesy of Daniel Dean, Nichols, N. Y.)

always plowed to its full depth, *viz.,* 8 to 10 or more inches, depending on the depth of the surface soil and the character of the sub-soil (Figs. 7-9). A good rule to follow is that of turning up from a half inch to one inch of sub-soil at each plowing when the surface soil is too shallow. In regions where the planting is delayed until the first to the fifteenth of June, and on lands that have a tendency to wash, it may be desirable as in the special case of alfalfa sod, to plow as late in the spring as it is possible, in order to turn under a goodly mass of the succulent leaves and stems of the clover plant. But whether plowing is done in the fall or the spring, it should be thoroughly done, and every effort should be made to conserve the moisture. Fall-plowed land, if not to be replowed in the spring, should be disked and harrowed as early as possible in the spring and then kept friable until the crop is planted. Spring-plowed land should be disked as plowed and kept mellow.

Preparation of the Seed Bed.—No expense should be spared in preparing the seed bed. The deeper it is prepared and the more finely it is pulverized, the more suitable it is for the production of a large yield. The choice of implements in fitting the land is, to some extent, a matter of personal preference. A heavy sod, if it has been well plowed, can probably be most quickly and satisfactorily put in shape for the crop by the use of the cutaway disk followed by a smoothing harrow. Some prefer the plain disk to the cutaway while still others like the Acme harrow. The latter harrow is especially valuable on a sod that tears up badly, as this implement slices rather than tears the sod apart. Get the land in as finely divided a condition as possible, as it is much easier to do it before planting than it is afterwards. If the land is lumpy, roll it with a heavy roller or clod-crusher and then harrow it, or else run a plank drag over it until the surface is smooth (Fig. 9). The old adage that "a stitch in time saves nine" is quite applicable to the proper preparation of the land.

QUESTIONS ON THE TEXT

1. What are some of the factors to be considered in the selection of a suitable soil for potatoes?
2. Of what importance is humus to the soil?
3. What crop should precede a potato crop?
4. When should the land be plowed?
5. How should an alfalfa sod be handled?
6. How would you handle a clover sod?
7. Where late planting is practised what variation in the plowing of the land is suggested?
8. What are the determining factors as to fall or spring plowing?
9. How would you proceed to handle fall-plowed land in the spring?
10. How would you handle spring-plowed land?

QUESTIONS SUGGESTED BY THE TEXT

1. What types of soil are used for potato growing in your region?
2. What soils have you that are not suitable for potato growing? Why?
3. What crops are grown preceding potatoes in your region?
4. What is the chief source of organic matter for local crops of potatoes?
5. How is the soil usually prepared by local growers?
6. Is spring plowing or fall plowing usually practised by local growers? Why?

CHAPTER V

FOOD REQUIREMENTS OF THE POTATO CROP AND HOW SUPPLIED

A well balanced and ample food supply is important in the production of any crop if profitable yields are to be secured. This is particularly true with respect to crops requiring a considerable expenditure of money and labor in producing and marketing them. The problem confronting the grower is that of supplying the necessary food elements for the production of a maximum crop with the least expenditure of money and effort. It is, therefore, essential to have somewhat definite information as to what these food requirements actually are, if they are to be intelligently supplied.

Chemical Elements in Plants.—Notwithstanding the fact that there are a great many thousands of different kinds of plants growing on the earth's surface, and that among these there is a great diversity in form and in color of foliage and flower, comparatively few chemical elements are drawn upon to produce them. Of the eighty or more known chemical elements it is claimed by the chemist that only fourteen of this number are commonly found in plants. These fourteen elements, according to Van Slyke[1], are calcium, carbon, chlorine, hydrogen, iron, magnesium, manganese, nitrogen, oxygen, phosphorus, potassium, silicon, sodium and sulphur. Fortunately most soils are sufficiently well supplied with all but four of these elements, *viz.* nitrogen, phosphorus, potassium and calcium. The first three of these elements are generally considered the essential ones as calcium is more generally present in soils at least in sufficient amount for the plant's needs than are the other three. However, there are many soils that are directly benefited, so far as their crop productive power is concerned, by an application of calcium. On the other hand not all soils require nitrogen, phosphorus and potash. Take, for example, the soils of the western portion of the United States, particularly the Inter-Mountain section, where it has been found that most of them are generally well supplied with both phosphorus and potash, but are wofully deficient in nitrogen, and especially in organic matter. In still other sections it has been found that there is, for the present at least, a sufficient supply of nitrogen, phosphorus and potash to produce a satisfactory crop. Generally speaking, the soils of the northeastern portion of the United States are benefited by an application of these chemical elements. It is apparent, therefore, that one must study his own soil requirements in order to determine whether they are lacking in any of the elements mentioned. It is also rather essential to any intelligent application of plant food to know what amount of nitrogen, phosphorus and potash a 200-bushel-acre potato crop removes from the soil.

Relative Amounts of Nitrogen, Phosphoric Acid, and Potash Removed by a 200-bushel-per-acre Crop of Potatoes.

Source of data	Nitrogen	Phosphoric Acid	Potash
	lbs.	lbs.	lbs.
Woods, C. D. and Bartlett, J. M.: Main Sta. Bul. 57, 1899	37.0	16.0	58.0
Van Slyke, L. L.: Fertilizers and Crops, p. 163, 1915	42.0	18.0	60.0
Voorhees, E. B.: Fertilizers p. 215, 1903	27.0	12.0	60.0
Fraser, S.: The Potato, p. 54, 1905	54.0	20.4	52.7
Grubb, E. H. and Guilford, W. S.: The Potato, p., 211, 1912	53.3	20.0	53.3
Average amount removed	42.66	17.28	56.8

These amounts removed could be supplied with about 270 pounds of nitrate of soda, 108 pounds of a 16 per cent acid phosphate, and about 110 pounds of muriate of potash. As a matter of fact, however, it is necessary to apply an excess of plant food in order to make good the losses that are almost certain to occur through surface washing, leaching, or through combination with inorganic substances present in the soil which may result in the formation of an insoluble compound. In any case, it is always advisable to supply from 50 to 75 per cent more plant food to the soil than the crop is likely to remove, in order to provide for the various contingencies mentioned.

The first consideration in the enrichment of a soil for the production of potatoes, after one has a thorough knowledge of its requirements, is that of the materials available for this purpose, their cost, and their economy of use. Outside of the mineral elements naturally contained in all soils there are three general sources of plant food of which the grower may avail himself in the enrichment of the soil. These three sources are: (1) green manuring or the turning under of growing crops, (2) farm manures, (3) commercial fertilizers.

Green Manuring.—The first of these three sources of plant food is available to every grower who is willing to take the trouble of growing a crop to be turned under. Those crops which are most valuable for this purpose are the well known members of the pea family, or legumes as they are more generally called. The alfalfa, clovers, peas, beans, cowpeas, soy beans, velvet beans, trefoils, and beggar weeds are included in this group. Each of these members has its own peculiar value depending on the soil and the

Approximate Amounts of Plant Food Constituents in one Legume Crop.

Crop	Yield per acre lbs. green matter	Per cent. of water	Nitrogen	Phosphoric Acid (P_2O_5)	Potash (K_2O)
Alfalfa	20,000	75	120 lbs.	30 lbs.	160 lbs.
Clover, alsike	16,000	82	80 lbs.	19 lbs.	48 lbs.
Clover, crimson	16,000	82	72 lbs.	19 lbs.	64 lbs.
Clover, mammoth	20,000	80	100 lbs.	24 lbs.	80 lbs.
Clover, red	12,000	80	66 lbs.	16 lbs.	60 lbs.
Clover, white	8,000	81	40 lbs.	16 lbs.	24 lbs.
Clover, sweet	20,000	80	110 lbs.	30 lbs.	100 lbs.
Field pea	10,000	82	50 lbs.	15 lbs.	50 lbs.
Cowpeas	12,000	84	54 lbs.	14 lbs.	54 lbs.
Soybean	10,000	75	50 lbs.	15 lbs.	60 lbs.
Velvet bean	20,000	75	110 lbs.	30 lbs.	110 lbs.
Vetch	10,000	84	50 lbs.	10 lbs.	45 lbs.

climatic conditions under which it must be grown. Of the non-leguminous plants, rye, crab-grass and buckwheat are probably the most commonly employed.

Considerable humus and plant food is added to the soil for an ensuing crop by simply turning under a good grass sod, or a cowpea, soybean or velvet bean stubble, but it does not compare with that added when the whole plant is turned under. The question for the grower to decide is whether it is more profitable to harvest the crop for hay, with the idea of feeding it to livestock and returning the manure to the land, than to turn it all under. The problem resolves itself into whether the grower has the livestock to which to feed the crop; if he has and is a good feeder it is probably more profitable to add the fertility to the land in the form of manure provided the manure is well cared for prior to its application to the soil. Experiments have demonstrated that more plant food is added to the soil when the crop is allowed to reach a fair stage of maturity before turning it under. This is comparable to what has been learned, regarding the best stage at which to cut silage corn in order to get the maximum feeding value out of it.

Van Slyke (*l.c.* p. 556) gives the following data relative to the average fertilizing constituents in various leguminous crops. A comparision of this data on cowpeas as presented in the following table, with that published by the Alabama,[2] New Jersey,[3] and South Carolina[4] stations shows a rather marked difference in results particularly in the case of the Alabama and South Carolina data.

Whether these differences were due to heavier yields of cowpeas or to variations in method of making analysis is not quite clear. A careful study of the data as a whole, cannot fail to impress the reader with the importance of employing leguminous cover crops in regions where they can be successfully grown; or in using clover

Comparison of Cowpea Analysis.

	Nitrogen	Phosphoric Acid	Potash
Van Slyke	54.0 lbs.	14.0 lbs.	54.0 lbs.
Alabama Station	123.27 lbs.	45.95 lbs.	101.9 lbs.
New Jersey Station	74.8 lbs.	18.8 lbs.	54.8 lbs.
South Carolina Station	205.0 lbs.	33.0 lbs.	155.0 lbs.
Average	114.3 lbs.	27.9 lbs.	91.4 lbs.

or alfalfa in the rotation system in northern sections for the enrichment of the soil. There are also other advantages from the use of green manures, or even in turning under the stubble of leguminous crops, quite apart from their fertilizing elements. The two most important benefits are those of the improvement of the physical character of the soil by increasing its porosity, and at the same time imparting to it a greater water holding and absorptive capacity. It also insures greater bacterial activity on the part of the soil flora particularly of the nitrifying organisms.

Farm Manures.—The composition of farm manures is extremely variable, because it is entirely dependent upon the nature of the manure, that is, whether horse, cow, hog or sheep manure, how the animals were fed that produced it, and the amount of care exercised in conserving their liquid and solid excrement. Van Slyke (*l.c.* p. 289) gives the following data regarding the percentages of plant food constituents in mixed farm manures. Assuming the average analysis to fairly represent the composition of a reasonably good grade of farm manure, the application of ten tons per acre would, theoretically, add 100 pounds of nitrogen, 50 pounds of phosphoric acid, and 100 pounds of potash. These amounts are largely in excess of the plant food requirements of a 200-bushel crop of potatoes.

It must be remembered, however, that only one-third to one-half or more of the plant food elements in farm manures are available to the crop to which it is applied. In view, therefore, of the rather unbalanced plant food constituents of farm manure, that is, the relatively low phosphoric acid and high nitrogen content of well preserved manures, it is really more economical to supplement the manure with a commercial fertilizer rich in phosphoric acid and low in nitrogen. An application of ten tons of manure per acre before plowing the land and 600 pounds of a 2-8-2 fertilizer, that is, 2 per cent of nitrogen, 8 per cent of phosphoric acid, and 2 per cent of potash, at the time of planting should give

Composition of Farm Manures.

	Nitrogen		Phosphoric acid		Potash	
	per cent.	lbs.	per cent.	lbs.	per cent.	lbs.
Lowest analysis	0.4	8	0.2	4	0.4	8
Highest analysis	0.8	16	0.4	8	0.8	16
Average analysis	0.5	10	.25	5	0 5	10

good results. This would add 12 pounds each of nitrogen and potash and 48 pounds of phosphoric acid or a total, including that contained in the ten tons of manure, of 112 pounds of nitrogen, 98 pounds of phosphoric acid, and 112 pounds of potash. While these amounts are not equal in phosphoric acid to a ton application of a 4-8-4 fertilizer, they contain more nitrogen and potash.

Manure Causing Scab.—Where entire dependence is to be placed on farm manures to produce a crop of potatoes, it is usually preferable to apply the manure to the preceding crop or, in the case of clover, after the first crop has been cut, to be turned under with the second crop of clover in the late summer or early autumn. This is advisable in order to avoid danger of loss from common scab infection, which, if present in the soil, is almost certain to cause more injury to the potato tubers than if manure were not used.

Commercial Fertilizers.—The use of commercial fertilizers in potato production is an almost universal practice throughout the Atlantic Coastal Plain section of the United States and throughout the greater part of New England. They are not used extensively in New York State outside of Long Island. Their use is by no means common in the Middle West or Northwest, though it is probable that in many sections they could be employed with profit. In the early trucking regions in the South the growers use a fertilizer containing a higher percentage of nitrogen than those in the late or main crop localities. This is primarily due to the fact that they are desirous of forcing a quick growth of the plant in order to hasten the harvesting of the crop. A formula used rather extensively in the Norfolk trucking section is one that analyzes 7 per cent ammonia, 5 per cent phosphoric acid, and 4 to 6 per cent of potash. A favorite formula at the present time in Aroostook County, Maine, is one carrying 4 per cent ammonia, 8 per cent phosphoric acid and 4 per cent of potash. A 5-8-7 is also used quite extensively. When Germany placed an embargo on potash, the Maine potato grower was using a fertilizer containing 8 to 10 per cent of potash; but with its sharp advance in price, and a very limited supply on hand, the fertilizer manufacturer found it impossible to offer goods containing over 5 per cent of potash; and only a very limited amount containing 5 per cent potash was obtainable at any price. A large percentage of the fertilizers, offered by the trade in 1916, contained no potash whatever, and one of the favorite no-potash fertilizers was one that analyzed 5-10-0. It was thought by the manufacturers, as well as the growers, that by increasing the percentages of nitrogen and phosphoric acid it would in a measure overcome the lack of potash. As a matter of fact, it had the opposite result in many instances; it had a tendency to induce an unhealthy condition in the plant, which, on the Washburn loam soils of Aroostook County, Maine, soon developed well marked cases of potash starvation, accompanied by the premature death of the plant. There is every indication that tubers produced on soil so deficient in available potash as to develop well marked cases of potash starvation in the growing plants, are not as suitable for seed purposes as are those that were grown on soil in which there was a sufficient supply of this element.

Amount of Commercial Fertilizer to Apply.—In most of the Atlantic Coastal Plain region the truck growers use all the way from 1500 to 2500 pounds per acre. The same amounts are used in Northern Maine. In the other New England States the amount varies rather widely, say from 800 to 1800 pounds with an occasional grower using a ton. In Western New York from 600 to 1200 pounds represent the average range of applications where commercial fertilizers are used at all. The same statement will apply to Michigan, Wisconsin, and Minnesota. The use of commercial fertilizers are comparatively unknown west of the Mississippi, except in the southwestern states such as Louisiana, Texas, and Oklahoma. In these states cotton seed meal has been the chief source of nitrogen.

FIG. 10—Distributing the second application of fertilizer with the potato planter from which the plow and covering disks have been removed. Aroostook County, Me.

The limiting factor in the use of commercial fertilizers in any community is that of the benefits derived from their use rather than their cost. As long as the increase in yield due to the application of commercial fertilizers is more than sufficient to offset their cost, the grower should make use of them. It is, of course, desirable to determine by experimentation just what element or elements are lacking in the soil, before engaging in any extensive use of commercial fertilizers.

Method of Application.—Farm manures may be broadcasted on the land by hand or with a manure spreader, either before or after the land is plowed. Some growers prefer to plow the manure under while others favor its application to the plowed land. When the land is plowed in the fall and it is not of a leachy nature, it is believed that better results will be secured by turning the manure under. When it is applied in the spring to either fall- or spring-plowed land, the application should be made before it is disked. In other words, to secure the best results from the manure it is necessary to have it thoroughly incorporated with the soil. Farm manures should not be applied to land known to be infested with the potato scab organism, as it is almost certain to increase the number of infected tubers. On such soils it is preferable to apply the manure to the preceding crop. There is less likelihood of

Fig. 11.—Broadcasting the second application of fertilizer. Aroostook County, Me.

injury to the tubers when the manure is applied to land in the late summer or early autumn and then plowed under.

In the case of commercial fertilizers, the method of application varies with the cultural practices followed in planting the crop.

Where the horse-drawn automatic or semi-automatic potato planters are used, they are generally equipped with a fertilizer distributing attachment which opens up a shallow furrow and drops the fertilizer, which, in turn, is mixed with the soil by the plow immediately in the rear of the fertilizer dropping tube, which opens a slightly deeper furrow for the reception of the seed pieces that are dropped immediately behind it. In New Jersey, Long Island, N.Y., and Maine it is customary to apply the full amount of fertilizer when planting the crop. A few growers, however, prefer to make a second application. Generally these are growers who apply over a ton per acre to the crop. Such growers usually apply about 1500 pounds per acre at the time of planting, and make the second application of from 500 to 1000 pounds over the row, just as the plants are about to push through the surface of the ground. This is usually done with the planter by removing the plow and covering attachment (Fig. 10). The fertilizer is either lightly harrowed in, or is covered over with soil. In some few instances a lime distributor is used in making the second application (Fig. 11). This broadcasts the fertilizer which is then cultivated into the soil.

In the South where the horse-drawn potato planter is not exten-

FIG. 12.—Applying fertilizer with a 3-row distributor.

FIG. 13.—Mixing fertilizer in soil with one-horse cultivator. Deep Creek, Va.

sively used, or, if employed, does not have a fertilizer distributing attachment, the common practice is to open furrows with a one or two-horse turning plow or a middle buster, and then sow the fertilizer in the furrow by means of a three or four-row fertilizer distributor, (Fig. 12) or with a one-row drill. The fertilizer is mixed with the soil by running a one-horse cultivator through the furrow (Fig. 13). The cultivator, when used for this purpose, is made as narrow as possible. In some sections, particularly in the Norfolk district, the growers make two applications in the furrow prior to planting. Both are made in the manner described; the first being applied a week or ten days in advance of planting, and the second just before the seed is dropped. The growers have a theory that the earlier application undergoes certain chemical changes in the soil, which render its plant food more readily available to the potato plant when it begins to push out its roots in quest of food. It has seemed to the writer that this practice has at least one disadvantage in that, when heavy rains occur between the time of its application and the planting of the seed, a large portion of the soluble plant food is washed away. Later applications are frequently made by the Southern truck growers. These are referred to as side-dressings, so named because the fertilizer is distributed along the side of the row after the plants have attained some size. This practice is often resorted to after the plants have received a check due to cold weather or a drought, in order to stimulate a quick growth. The fertilizer is oftentimes distributed by hand, but it may be applied with a one-row drill. When a side-dressing is applied, it is immediately worked into the soil.

A successful grower in New York State broadcasts the major portion of his fertilizer application before second-plowing his potato land in the spring. The reason given for this practice is that it places the commercial fertilizer several inches below the surface of the soil and, at the same time, distributes it uniformly over the whole area, thus compelling or stimulating the roots of the plant to penetrate deeper into the soil, as well as to send out their laterals in all directions in quest of the plant food contained in the fertilizer. Through the development of this extensive root system, the plant is better able to withstand drought or other unfavorable conditions and in consequence thereof can be counted on to give a better yield, one year with another, than will those having all their plant food immediately beneath or above them, as is the case when the whole application is made in the drill row. In the particular example just cited, the crop grown is a late one. It is doubtful if such a practice would be desirable in the growing of an early crop, as earliness of maturity is the prime consideration.

QUESTIONS ON THE TEXT

1. What is the grower's problem as regards an ample food supply?
2. How many of the eighty or more chemical elements now known are found in plants? Name them.
3. Which of the elements are generally considered the essential ones?
4. Which are most commonly deficient in your local soils?
5. What element or elements are lacking in the Inter-Mountain section of the United States?
6. In general what do the soils of the northeastern United States require?
7. What are the relative amounts of nitrogen, phosphoric acid and potash removed by a 200-bushel-per-acre crop of potatoes?
8. How much nitrate of soda, 16 per cent acid phosphate, and muriate of potash would be required to supply this loss to the soil?
9. What sources of plant food may he use in the enrichment of his soil?

10. Explain the term "green manuring" and give a concrete example of its use.
11. What leguminous and non-leguminous crops are most generally used for the enrichment of the soil?
12. What stage of maturity should a crop reach before turning it under in order to secure a maximum amount of benefit?
13. How does the nitrogen, phosphoric acid, and potash content of an alfalfa crop compare with that of the other leguminous crops mentioned in the legume table?
14. What is the average percentage content of nitrogen, phosphoric acid, and potash of a reasonably good grade of farm manure?
15. How many pounds of each would be added by an application of ten tons of manure per acre?
16. What proportion of the plant food elements in farm manures are available to the crop to which it is applied?
17. What supplementary fertilizing material is it advisable to use in connection with farm manures in sections where the mineral elements are lacking?
18. Where entire dependence is to be placed on farm manures, when are they best applied? Give reason.
19. Why does the southern potato grower use a different grade of commercial fertilizer from that of the northern grower?
20. What fertilizer formula is used rather extensively in the Norfolk trucking section?
21. What is a favorite formula in Aroostook County, Maine?
22. What was the result of using a no-potash fertilizer?
23. What amount of commercial fertilizer is it advantageous to use?
24. What is the probability of potato growers in the Middle West becoming large users of commercial fertilizers?
25. What is the best way of determining what plant food elements are lacking in any particular soil?
26. Are there any disadvantages in the use of farmyard manures? Give reasons.
27. How may the possibility of injury from common scab be avoided?
28. How are commercial fertilizers usually applied to the land in the North? In the South?
29. What is the theory involved in applying a part of the fertilizer some days in advance of planting the crop?
30. What is meant by a side-dressing? How is it applied?

QUESTIONS SUGGESTED BY THE TEXT

1. What amounts of farm manure are applied to potato fields by local growers?
2. What legume crops are commonly turned under for local crops of potatoes?
3. Calculate the amounts of the three fertilizing constituents applied in these ways by one grower.
4. What fertilizer formulas are used by local growers?

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1. VAN SLYKE, L. L. *Fertilizer and Crops.* pp. 15, 163, 289, 556, 1917.
2. *Alabama Sta. Bul.* 14 (n. ser.) 1890, pp. 5-9.
3. *New Jersey Sta. Rpt.* 1893, pp. 146-150.
4. *South Carolina Sta.* 2nd. Ann. Rpt. pp. 169-179.

CHAPTER VI

CROP ROTATION

Necessity of Crop Rotation.—A system of agriculture which is not based on a definite rotation of crops can hardly be regarded as measuring up to modern agricultural teachings. The theory on which crop rotation is based is that of conserving the natural fertility of the soil by maintaining a proper balance between its mineral elements, sustaining or increasing the humus content, thereby improving its physical condition and, at the same time, restraining the development of injurious fungous and insect pests. Bolley[1] has recently demonstrated that the constantly diminishing wheat yield in the Middle West is not so much due to a depletion of soil fertility as to the cumulative effect of constantly increasing soil infection by fungi preying upon the roots of the growing wheat plants. He has also found that a rotation of crops on these lands has served to give increased wheat yields, when this cereal followed other crops such as corn, oats or potatoes, in the rotation scheme.

Systems of Crop Rotations.—At the present time, comparatively few American potato growers practise a definite crop rotation system, whereby but one crop of potatoes is grown during the rotation. For example, in the far-famed Aroostook County in northern Maine, where the potato may be said to be the only cash crop grown by a majority of the farmers, it is generally understood that a three year rotation is practised. Theoretically, the rotation is: potatoes the first year, oats seeded with clover and timothy the second, and a clover crop the third year. The clover rowen, or second crop clover, is plowed under in the late summer or early autumn for the ensuing potato crop. As a matter of fact, however, comparatively few Aroostook farmers adhere to this rotation. A large proportion of them take two, three, or even more potato crops in succession before the land is seeded down. This is particularly true on land which is especially well adapted to potatoes. Fields have been noted during the past two seasons that were producing their ninth consecutive crop of potatoes. Such extreme cases of cropping are, of course, comparatively rare; but the taking of two or three crops in succession is quite common. On the other hand, however, here and there may be noted a grower who is adhering to a well-defined system of crop rotation. The author has in mind one party who for years has been practising a five year rotation system, allowing the land to remain in grass three years, instead of one. On this farm fifty acres of potatoes are grown annually. It is hardly necessary to say that, under this system of cropping, profitable yields of high class potatoes are being secured.

Interplanting.—In the trucking regions of the Atlantic seaboard, from New Jersey to Florida, a peculiar system of cropping is in vogue.

Fig. 14.—Potatoes interplanted with corn.

In Florida, for example, the potato crop is planted from the latter part of December to the middle of February, and is harvested from the latter part of March to the latter part of May. The land is very frequently planted to corn, and occasionally to sugar cane, some time in advance of harvesting the potato crop. In the case of the corn, the planting is usually done with a one-horse planter, so constructed that the seed dropping attachment is set to one side of the center, which permits the drilling in of the corn on the side of the potato ridge (Fig. 14). When the harvesting of the potatoes is delayed by unseasonable weather, or by unfavorable prices, the corn plants frequently attain a height of six to twelve or more inches before the potatoes are removed (Fig. 15).

In such instances, of course, and in fact in all cases where the sides of the potato ridges are planted with corn, the harvesting of the crop is very largely done by hand. By exercising a reasonable degree of care it is possible, by using a small one-horse turning plow, to plow out the potatoes. This materially reduces the hand work and effects a considerable saving in labor cost.

The sugar cane cuttings are usually embedded near the bottom of the furrow, and are sufficiently removed from the potato plants to allow the use of a potato digger.

Annual Crop After Potatoes.—Where interplanting is not practised, the land may be planted to corn as soon as the potatoes

Fig. 15.—A newly harvested potato field showing size of corn plants. Ordinarily it is not considered desirable to have the intercrop so far advanced before the potato crop is removed. Hastings, Fla.

are out of the ground; or the seed is dropped in the furrow between the rows prior to digging. The operation of harvesting the crop covers the corn. Or it may be seeded to crab-grass and allowed to produce a crop of hay. When planted to corn, cowpeas are very frequently sowed among the corn at the time it receives its final cultivation. The cowpeas make a fair growth of vine, conserve and accumulate nitrogen in the soil, and at the same time provide a considerable quantity of vegetable matter to be plowed under for the next season's crop of potatoes, or it may be made into hay. On most of the potato farms around Hastings, Fla., a crop of early potatoes is produced every season, with seemingly little, if any, deleterious results, where intelligent care is given to the preparation of the land and the care of the crop.

What has been said regarding Florida conditions applies almost equally well to the Charleston, S. C., district. That is, the potato crop is followed by corn, cowpeas, cotton, or hay.

Strawberries with Potatoes.—In the Norfolk and Eastern Shore trucking regions of Virginia and Maryland, various rotation and intercropping methods are pursued. One rotation, frequently observed by the writer, is that of interplanting the potato field with strawberry plants. When this practice is followed, the potato rows are spaced from four to five feet apart, the young strawberry plants being set between the rows (Fig. 16). In this

Fig. 16.—Strawberry rows five feet apart interplanted with potatoes. Norfolk, Va.

way a partial crop of potatoes is secured while the berry plants are becoming established. Another way is to interplant with string beans, or with corn, when an early crop is desired. Where the potato crop is the sole occupant of the land during its growing period, it may be followed with a crop of cowpeas, soybeans, millet, or corn. Occasionally a second crop of potatoes may be grown. It is not an infrequent practice to grow potatoes two or three years in succession on the same land. There is no distinctive crop rotation system between which might be said to apply to this trucking section.

Potatoes Continuously.—In addressing an audience of potato growers in the Louisville, Kentucky, district some time ago, the author was greatly surprised to have a gentleman arise at the close of the meeting and make the statement that he had been annually removing two crops of potatoes from land that has been devoted to this system of cropping, to his actual knowledge, for 33 years. He, furthermore, stated that he had been unable to detect any diminution in the crop, and was even inclined to believe that better yields were being secured now than formerly. Fortunately, such severe cropping is extremely rare. It is a common practice in that section, however, to repeatedly grow one crop of potatoes per year on the same piece of ground. Such a practice can hardly be regarded as a wise policy to pursue on any soil or in any locality.

Potatoes After Alfalfa.—In the Western potato producing centres, such as the Greeley and Carbondale districts in Colorado, a fairly definite crop rotation system is followed. For example, in the Greeley section potatoes are usually planted on an alfalfa sod land. When potato production was at its zenith in this locality, potatoes frequently followed potatoes for two or three years in succession. At present sugar beets may alternate with potatoes, after which one or two grain crops follow before seeding it back to alfalfa, in which crop it may remain from three to four years. Some growers secure two crops of potatoes in the rotation scheme; the first being grown on alfalfa sod, after which a crop of grain follows and then a second crop of potatoes. When potatoes follow potatoes, the second crop from alfalfa sod is frequently better than the first one. These results are obtained only when the land is reasonably free from infectious diseases that prey upon the potato plant.

At the Greeley Experiment Station, operated conjointly by the United States Department of Agriculture, the Weld County Commissioners and the Colorado State Experiment Station, a definite four year crop rotation has been established, in which potatoes are grown on alfalfa sod, followed the next season by oats seeded with alfalfa, the oats serving as a nurse crop, and indirectly returning a fair yield of grain; alfalfa is grown the following two seasons. The same rotation has been established at the Jerome Experiment Station, Jerome, Idaho, which is being operated by the United States Department of Agriculture.

In the Carbondale district a very similar system of crop rotation is in vogue, except that sugar beets are not grown in that region. The general practice is to take two crops of potatoes in succession.

Potato-Barley Rotation.—In the "tule" lands of the Sacramento and San Joaquin delta, regions where potatoes have been the chief money crop for a number of years, the common practice is to take two or three potato crops in succession, followed by a crop of barley, and then back to potatoes for another two years. The result of such a system of crop rotation has been to so thoroughly infect the soil with potato diseases as to make the crop, in many instances, an unprofitable one to grow.

No Uniform Rotation.—From the foregoing statements, it is evident that there is no general and well-defined system of crop rotation that is rigidly adhered to in any of the large potato growing centres. The desirability of rotating crops is well understood, but the temptation to grow a money crop as often as possible is great; so that the ultimate benefits accruing from the practice of a sane crop rotation system, are often sacrificed to the prospect of immediate gain.

A potato crop rotation system suitable to each potato producing section could easily be adopted if the growers desired.

The three-year system, supposedly practised by the Maine potato growers, is probably as desirable as could be devised for that section. As a rule, a good clover stand is easily secured; and the crop grows luxuriantly, so it affords a cheap source of plant food and serves to maintain and even increase the humus content of the soil, thereby keeping it in good physical condition.

Alfalfa in the Rotation.—Where alfalfa can be grown as successfully or more so than clover, it should be substituted for it, and at least a four year rotation adopted. It may be that, where it seems desirable to allow the land to remain in alfalfa three or four years, two crops of potatoes may be permissible in the rotation by growing a crop of grain between them.

The following rotations are suggested for alfalfa growing sections:

I. 1st year, potatoes on alfalfa sod; 2nd year, oats, wheat or barley seeded with alfalfa; 3rd and 4th years, alfalfa.

II. 1st year, potatoes on alfalfa sod; 2nd year, wheat; 3rd year, potatoes; 4th year, oats or barley seeded with alfalfa; 5th, 6th and 7th years, alfalfa.

For clover growing sections where alfalfa does not succeed, two rotations are here given:

I. 1st year, potatoes on clover sod; 2nd year, oats or barley, seeded down with clover, timothy and red top; 3rd year, hay.

II. 1st year, potatoes on clover sod; 2nd year, oats or barley, seeded with clover, timothy, bluegrass and redtop; 3rd and 4th years, hay.

In the trucking sections of the South the diversity of crops grown, and the fact that two or three truck crops may be grown annually, makes the task of devising a suitable crop rotation system an extremely perplexing one. Where careful attention is given to the plowing under of cover crops, potatoes may follow potatoes year after year, with apparently little, if any, diminution in yield or in quality. On the other hand, a safer and saner plan to follow would be not to grow potatoes oftener than once in two years; always planning to turn under some cover crop for the ensuing crop of potatoes.

QUESTIONS ON THE TEXT

1. On what is the theory of crop rotation based?
2. What has Bolley demonstrated to be one of the reasons at least, for the constantly diminishing wheat yield in the Middle West?
3. What crop rotation is supposed to be followed by the Aroostook, Maine, potato grower?
4. What is the actual practice of a large majority of the Maine growers?
5. What system of crop rotation is followed in Florida?
6. What is the system of crop rotation practised in the trucking regions of Virginia and Maryland?
7. What rotation is practised in the Louisville, Kentucky, district?
8. What is the practice in Colorado and other western states?
9. What is the crop rotation system followed at the Greeley and Carbondale Stations?
10. Give crop rotation system followed in the reclaimed "tule" lands of the Sacramento and San Joaquin delta regions of California.
11. What crop rotation system is thought most desirable for the Maine potato grower?
12. What are the relative values of clover and alfalfa?
13. Give four-year rotation suggested with alfalfa.
14. Give seven-year rotation suggested with alfalfa.
15. Give three-year rotation suggested with clover.
16. Give four-year rotation suggested with clover.
17. What problems confront one in devising an acceptable crop rotation system for the southern grower?

QUESTIONS SUGGESTED BY THE TEXT

1. Give the most common rotation by local potato growers.
2. What is the next most common? Give any other rotation in use.
3. Compare and criticise these rotations.
4. Describe any interplanting with potatoes which you have seen.
5. What bad effects have local growers had from too continuous cropping of the same soil with potatoes?

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CHAPTER VII

VARIETIES TO GROW, KIND AND AMOUNT OF SEED TO USE, AND PLANTING METHODS

Choice of Varieties.—The first question to decide in the production of a crop of potatoes is that of the variety to grow. A variety should be selected that is adapted to the region in which it is to be grown. As a rule varietal adaptations are now fairly well recognized in most large potato producing centers or districts. If the crop to be produced is intended to supply an early market it will, of course, necessitate the choice of an early variety. The choice of a variety must, therefore, be governed by its adaptability to its environment, and the season of the year in which it is to be marketed. There is one other consideration in the choice of a variety, and that is whether it is to be grown for seed or for table purposes and whether the tuber is rough or smooth (Fig. 17). The leading commercial varieties of potatoes are rather few in number compared with the long list of varieties or varietal names catalogued by the seedsmen of this country. The following list is believed to include all the varieties of strictly commercial importance.

Early Varieties	*Medium or late maturing varieties*	
Irish Cobbler	Burbank	Pearl
Triumph	Russet Burbank	McCormick
Early Ohio	Rural	Perfect Peachblow (Red McClure)
Spaulding No. 4	Russet Rural	Brown Beauty
	Green Mountain	American Giant
		Chas. Downing (Idaho Rural)

To this number might be added a supplementary list of varieties, such as the Early Rose, Beauty of Hebron, White Rose, and Up-to-date.

As the above varieties, with but two or three exceptions, are discussed in more or less detail in Chapter XXII, further elaboration is unnecessary, beyond saying that it should be understood that the Green Mountain, Rural, Burbank, etc., include the various members of the groups they represent. The Brown Beauty is evidently a variety of English origin as yet unidentified. It is the leading variety grown in the San Luis Valley district in Colorado where it is very popular. The White Rose is a popular variety in certain sections of California. A variety masquerading under the name of the Oregon White Rose, and another under the name of British Queen have become popular in western Oregon and certain localities in California. The two varieties seem to be identical and both are improperly named. Our own observations lead us to believe that they belong to the Up-to-Date group of potatoes.

FIG. 17.—A uniform lot of high grade seed stock, grown on the Sweet ranch, Carbondale, Col.

Kind of Seed to Use.—The importance of using good seed potatoes can scarcely be overemphasized. The customary practice of using what is left from the season's crop, after marketing or consuming the best of it, must be discontinued if the present quality and yield of the potato is to be materially improved or increased. It is as useless for the potato grower to expect maximum yields from inferior seed stock, as for the dairyman to hope to develop a superior milking strain from scrub stock. Nature does not work in that way.

Good Seed Defined.—Good seed may be described as stock

Fig. 18.—High grade immature perfect Peachblow seed stock grown on the Sweet ranch, Carbondale, Col. A desirable size to plant whole. Courtesy of L. D. Sweet.

that is pure with respect to the variety; that has been produced by healthy, vigorous, heavy-yielding plants grown under favorable climatic conditions; that is somewhat immature, reasonably uniform in size and shape (Figs. 18 to 21), and firm and sound, with the first sprouts beginning to develop at planting time. Seed of this character is now procurable in somewhat limited quantities from growers who have recently begun to specialize in seed production in Maine, Vermont, New York, New Jersey, Maryland, West

Fig. 19.—Seed tubers showing desirable stage of germination; first sprouts just pushing out.

Virginia, Michigan, Wisconsin, Minnesota, Nebraska, Colorado, Idaho, Oregon, Washington, and California. In all of these states provision has been made for the inspection and certification of the seed stock of growers who have made proper application for such inspection service, and whose fields and the crop harvested from same have been found to fulfil the inspection requirements. As yet, the amount of seed available in these various states represents but a small fraction of that required for planting the total acreage of the state or the country as a whole.

Certified seed necessarily commands a considerable premium over that which has not been inspected, but the extra cost of the

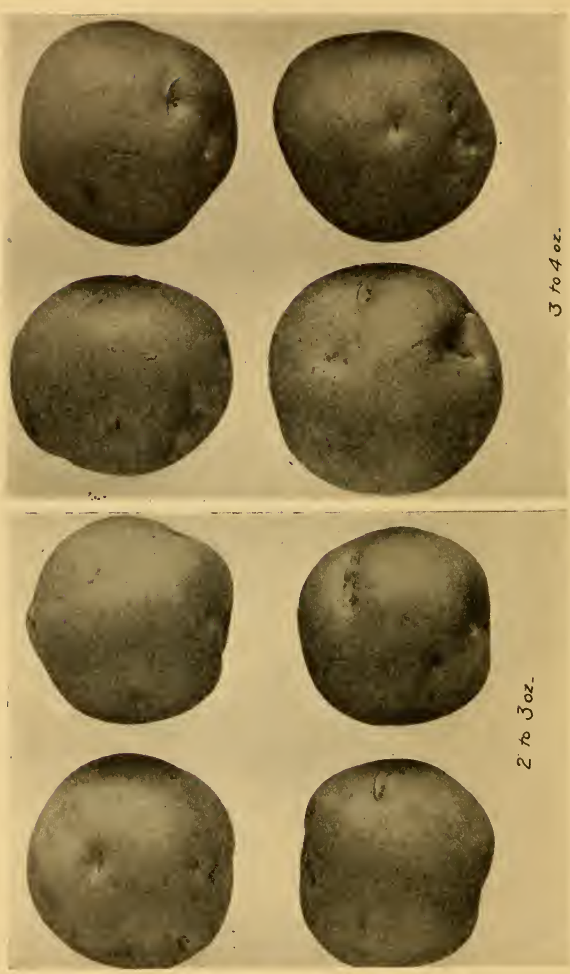

FIG. 20.—Desirable Irish Cobbler seed potatoes. Seed stock of this size and shape from healthy and productive plants can be depended upon to give satisfactory yields.

seed is slight as compared to the increased yields which may be expected from the use of good seed and the crop insurance which it affords.

Seed disinfection is discussed in the chapter on diseases.

Greening and Germinating or Sprouting Seed.—The practice of greening and germinating seed potatoes before planting them, in order to hasten the development of marketable tubers, is one that is commonly employed by growers of early potatoes in Great Britain and on the Continent, but is little used by American growers. The British growers use a special seed tray or flat, con-

Fig. 21.—Greened and well-germinated Irish Cobbler seed tuber. These sprouts are about the right stage of development. Note how short and stubby they are. Such sprouts are tough and are not easily broken off.

structed with corner posts from four to five inches higher than the sides, to which a narrow strip of board is nailed across the upper end. This strip serves as a handle in lifting or moving the flats and, when tiered one above another in the germinating room or house, provides an open space between the flats. The dimension of the tray is immaterial, except that it should be of a convenient size to handle. A tray having an outside dimension of 16 by 30 by 3 inches has been found by the writer to be very convenient to handle (Fig. 22). Such a tray, when filled with medium sized tubers, will hold approximately fifty pounds. The primary object of the flats is to furnish a convenient receptacle for the selected seed tubers, in which to expose them to light and sufficient heat to induce slow growing but vigorous terminal sprouts. The tubers are placed in the flats with the seed end uppermost, with usually but one layer to a flat. By placing the seed end uppermost it tends to stimulate the development of strong sprouts from the bud eye clusters, which, in the presence of light, remain short and stubby and are not easily broken off (Fig. 21). Many of the English growers place their seed in the trays in the autumn or early winter. Under favorable conditions, a development similar to that shown in figure 23 will be obtained in from four to eight weeks, depending on the season of the year in which they are placed in the trays.

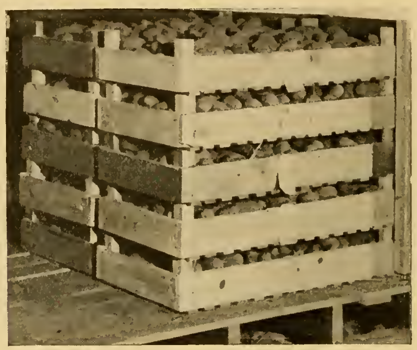

Fig. 22.—Tiers of 16x30x3 inch slat-bottomed seed trays, used for storing small lots of seedling potatoes. Such trays are suitable for germinating seed in the light.

Not all varieties respond alike to this treatment: in the Rural, for instance, the only eyes producing sprouts are usually those of the seed end (Fig. 21) whereas in the case of the Green Mountain, lateral eyes are just as likely to start into growth as the terminal ones.

Where shallow trays are not available it is possible to green and germinate the seed tubers by spreading them out rather thinly on a floor or the ground, where they can be protected from frost and at the same time be exposed to light during the daytime. By turning over the tubers every four or five days with a wooden rake or a potato scoop shovel, most of the tubers will be exposed to the light during some portion of the germinating period. Two to four weeks exposure will usually be enough to start germination sufficiently to enable the one who cuts the seed to select those eyes that show an active growth.

The benefits derived from greening and germinating the seed before planting it are not confined to the securing of a better stand and a quicker maturity, but it is claimed that a heavier yield is also obtained. Greig[2] reports increased yields from germinated

FIG. 23.—True to type Peachblow seed potatoes, showing the master sprout, which is the strongest sprout the potato can produce, and if it is allowed to grow no other sprout will be started. Courtesy L. D. Sweet, Col.

over ungerminated seed of from 34 to 39.5 bushels per acre. Still larger increases are mentioned[1] in which gains of from 61.6 to 74.7 bushels were obtained. The extent to which the sprouting of seed potatoes is practised in Great Britain can be judged from the following item which appeared in the Agricultural Gazette, volume 87, p. 188, 1918, "The Food Controller has decided, in special circumstances, to grant licenses to dealers to sell sprouted seed potatoes at a price not exceeding 30 shillings per ton in excess of the price allowed for the same variety of unsprouted seed potatoes." Some of the larger Jersey Island potato growers sprout hundreds of tons of seed potatoes each year.

In America, this method of securing earliness of maturity of the resultant crop offers greater possibilities, in the writer's judgment, to the growers of the North than of the South. The reason for this is that the southern grower ordinarily plants his early potato crop when the ground is cold, and while cool and even quite frosty nights prevail. Under these conditions the seed pieces are

Fig. 24.—An extensive root is developed before the stems appears above ground.

slow in germinating, and it matters little whether they are sprouted before planting or not, because the unsprouted seed has ample time to germinate and become well rooted before the upper layers of soil are sufficiently warm to stimulate stem growth (Fig. 24). It is, of course, desirable to have the seed exposed to light and heat a week or two before planting; but it is questionable whether much benefit is derived from a prolonged greening, such as is practised by overseas growers.

Size of Seed Piece.—The question of size of seed piece and whole vs. cut seed is one that has engaged the attention of growers and scientists for over a century and is still not fully answered. The superiority of whole over cut seed or of cut seed over whole seed has been repeatedly demonstrated for both; and a student of the literature of this subject soon arrives at a point where he is convinced that the question of superiority of whole or of cut seed is one of environment rather than of actual influence of seed piece. In general, the experimental evidence indicates rather clearly that, within reasonable limits, the larger the size of the seed piece used the larger will be the total yield. These results are generally secured, however, at the expense of size; that is a larger percentage of the crop will be too small for table purposes. This is particularly true with respect to whole seed.

Relation of Size to Amount of Seed per Acre.—Hardenburg[3] as a result of a review of the literature on size of seed piece, concludes that in many of the experiments, false conclusions have been reached, through the neglect of the investigator to take into account the amount of seed used per acre. He illustrates his point as follows: "In tests comparing the influence on yield of whole, half, quarter, and eighth tubers, the results have generally favored the whole tuber for seed, and it has been concluded that the larger the seed piece planted, the greater the yield is likely to be. In reality, eight times as much seed has been used per acre when whole seed has been used as when eighth tubers are planted ......Most of these experiments have, therefore in reality not shown that whole tubers are to be preferred to eighth tubers, provided the eighth tubers are planted enough closer in the row to consume the same amount of seed per acre as would be used in case whole tubers were planted."

In the main Hardenburg's point is well taken. It is a fact that most of the experimental work that has been done on size of seed piece has not taken into account a study of the most economical distance or spacing of the various sizes of seed pieces in the row. There is no question but that much of the apparent superiority of large over small sizes of seed pieces has been due to the fact that the spacing of the pieces in the row have more nearly approached the most economical distance for the large sized seed piece than of the smaller one. For example, a study of three ounce whole tubers with three ounce halved tubers, that is a one and a half ounce seed piece, with the spacing in each instance sixteen inches apart, does not afford a fair basis of comparison; because it is altogether probable that if the one and a half ounce seed pieces had been spaced ten or twelve inches apart their total yield would have been much greater per acre than at sixteen inches apart.

On the other hand, it is altogether likely that if the three-ounce whole tubers had been given the closer spacing, the yield of marketable tubers would have been materially decreased. A careful study of the right spacing to allow for different sizes of seed pieces in order to secure a maximum yield of marketable tubers is needed for each of the leading commercial varieties, in order to furnish a comparable basis for the determination of the relative value of whole vs. cut seed or large vs. small seed, regardless of whether it is whole or cut.

Fig. 25.—Seed-cutting hopper-boxes with stationary knives greatly facilitate the task of preparing the seed for planting. Courtesy of Daniel Dean, Nichols, N. Y.

When such studies have been made, it is quite likely that it will be found that too large or too small seed pieces, whether they are whole or cut, are not economical to use; and that the most desirable size of seed piece from the standpoint of net marketable yield will involve the use of a much larger quantity of seed than is now ordinarily employed.

Influence of Season.—It will also be found that different seasonal conditions favorably or adversely affect the results secured from different sizes of pieces even with proper spacing. For example, maximum results from whole tubers or from large sizes of cut seed can only be secured when there is sufficient available plant food and moisture in the soil to enable the plants to develop the tubers they set to a marketable size. It is also equally certain that small sizes of seed pieces are more likely to be injured by unfavorable soil or weather conditions after planting. If the soil is too dry, many of the seed pieces will fail to grow; and if it is too wet and cold, it is obvious that more of them will decay than of the larger sizes of seed pieces, particularly if whole seed has been planted. Neglect to take these and many other factors into consideration has led to numerous erroneous conclusions relative to the merits of large and small sizes of seed pieces.

Size in Irrigated Regions.—It is believed that in the irrigated regions of the West, where it is possible to supply the necessary

Fig. 26.—Cutting with stationary knife. The cutting edge of the blade should face in the same direction as the operator. Both hands are free to handle the tuber.

amount of moisture, the use of medium sizes of whole seed—say from 2 to 4 ounces in weight—of such varieties as the Rural New Yorker No. 2 and the Russet Burbank, will give better results than cut seed. There is reason to believe that in the case of the Charles Downing (Idaho Rural) the use of whole seed will be found undesirable, on account of its habit of producing more stems per given weight of seed piece than the other two varieties, and also to its inherent tendency to set a larger number of tubers per stem. It is apparent, therefore, that the variety itself is an important factor in determining the best size of seed piece to use.

General Practice Regarding Size.—Generally speaking, it is advisable to use a liberal size of seed piece, one weighing from one and a fourth to two ounces. As a rule, this will contain from one to three eyes. A three-ounce tuber cut in two or a four-ounce cut into three pieces has given very satisfactory results. The list of references on size of seed piece to use is by no means a complete

Fig. 27.—A set of adjustable knives fastened in a frame resting on a slat crate. A sharp blow from the wooden mallet forces the tuber through thereby dividing it as many times as there are blade sections covered.

one, but it will serve to show the amount of interest shown in this subject.

Cutting the Seed.—For the most part, seed potatoes are cut by hand rather than with automatic cutters; but the scarcity and high cost of labor and the continual improvement of automatic seed-cutting implements are having a tendency to increase their use, even though they are not as satisfactory as hand work. Thus far, no automatic seed-potato cutter has been devised which is able to distinguish between weak and strong eyes or no eyes at all; hence there is bound to be a certain percentage of seed pieces which will not produce plants, or if they do, they will be weak. On the other hand, all seed pieces that have been carefully cut by hand will contain one or more strong eyes (Fig. 24).

A seed-cutting box or hopper such as that shown in figure 25 with stationary knife blade, or without the hopper as shown in figure 26, greatly minimizes the labor of cutting seed. The home-made device shown in figure 27, if used by a careful operator, will

Fig. 28.—An 8¼ ounce Green Mountain tuber before cutting.

Fig. 29.—First step in cutting the 8¼ ounce tuber. Cut from seed to stem end.

give a low percentage of eyeless seed pieces. Figures 29 and 30 illustrate the process of cutting a large tuber (Fig. 28) into single eye pieces. The tuber should be cut so as to make blocky rather than wedge-shape seed pieces (Fig. 30). The advantage of a blocky seed piece is that it is handled better in the planter, and is less likely to dry out or to decay in the ground if the weather conditions are unfavorable.

When to Cut Seed.—As a rule, seed potatoes are cut about as required for planting; but when large acreages are to be planted and labor is scarce, it is often found more economical, as well as more convenient, to cut the seed in advance of the planting season. One of the most noted examples of cutting seed considerably in advance that has come to the writer's attention, is the practice of the growers in the Louisville, Kentucky district of cutting their seed potatoes, during December and January, for not only their spring crop but the fall one as well. In other words, part of the December and January cut seed is planted in March or early April, and the balance used for the second or fall crop in July. When

FIG. 30.—Final result in cutting an 8¼ ounce tuber into as many one-eye seed pieces as possible. Pieces at seed end have more than one eye. Note blocky shape of seed pieces. Average weight of pieces is ¾ of an ounce.

the seed is cut considerably in advance of its use, care must be exercised in handling the freshly cut material in order to avoid injury from overheating while it is curing.

Dusting Freshly Cut Seed.—The freshly cut seed handles better if sprinkled as cut with land plaster, air-slaked lime, or flowers of sulfur. These materials tend to dry the cut surface, and lessen the danger from heating if the weather is warm and the seed is not planted immediately.

Treatment of Seed.—The curing or drying process is facilitated by the use of one of the absorbents mentioned, and then placing the seed in slatted crates or spreading it out, in a thin layer, on the floor of a frost-proof house, if in the winter season, turning it over once or twice during the first twenty-four hours, and once during each of the following two days; after which the cut surfaces are generally dry enough to permit of being stored in barrels, sacks, or bins until needed for planting. Some growers prefer to handle their seed in this manner rather than to cut it as needed, claiming that they obtain much better results. But, whatever the method adopted, the important thing to remember is that, if the weather is warm, freshly cut seed develops heat very rapidly and that, under these conditions, its vitality is quickly injured. Many a poor stand has been attributed to the poor quality of the seed stock or to the imperfect operation of the planter when, in reality, the real cause was due to improper handling of the cut seed.

Rate and Distance of Planting.—The rate or distance of planting should be largely governed by the following factors: (1) the variety grown; (2) the natural normal rainfall of the section, and the moisture-holding capacity of the soil; (3) the supply of available plant food it contains; and (4) the size of the seed piece used. In some sections in Europe early varieties are frequently planted in rows 24 inches or less apart, with an 8-inch to 12-inch spacing in the row. Similar close planting was noted near Rimouski, Province of Quebec, Canada, in 1918. In this country the rows are seldom less than 30 inches apart and only occasionally at that distance. As a rule such varieties as Irish Cobbler and Triumph are spaced from 32 to 34 inches apart and from 8 to 12 inches apart in the row.

The following discussion on spacing is from Farmers' Bulletin 1064[4]: "In Aroostook County, Maine, early varieties such as the Irish Cobbler, Triumph, and Early Rose are usually planted in rows 32 to 34 inches apart and from 8 to 12 inches apart in the row. The Green Mountain, which is the leading late variety of that region, is planted in rows from 34 to 36 inches apart and the plants in the row, 10 to 14 inches apart, depending on the size of the seed piece used."

The table in Bulletin 1064, shows the number of seed pieces required for an acre when planted at different distances. A study of the data presented in this table show that the closest spacing, 30 by 8 inches, would require 26,136 seed pieces to the acre as compared with 14,520 for a spacing of 36 by 12 inches, which is the more common planting practice. The wider spacings included in the table are not infrequently encountered in the dry-farming sections of the West, where the deficiency in moisture makes it impossible to grow potatoes successfully at the distances usual in the humid areas of the United States.

"A comparison of the two extremes in spacing shows 26,136 seed pieces in one and 3,630 in the other, the ratio between the two being 1 to 7.2; in other words, the number of seed pieces required to plant an acre 30 by 8 inches apart would plant 7.2 acres 48 by 36 inches apart.

Number of seed pieces required to plant an acre of potatoes at different spacings.

Rows apart	Pieces of potato seed required at stated spacing distances (number)							
	8 inches	10 inches	12 inches	14 inches	16 inches	18 inches	24 inches	36 inches
30 inches	26,136	20,909	17,424	14,935	13,068	11,616	8,712	5,808
32 inches	24,502	19,602	16,335	14,001	12,251	10,890	8,168	5,445
34 inches	23,061	18,449	15,374	13,178	11,531	10,249	7,687	5,125
36 inches	21,780	17,424	14,520	12,446	10,890	9,680	7,260	4,840
42 inches	18,669	14,935	12,446	10,668	9,334	8,297	6,223	4,149
48 inches	16,335	13,068	10,890	9,334	8,168	7,260	5,445	3,630

Amount of Seed Required.—"The number of bushels of seed employed in planting an acre of potatoes varies considerably in different parts of the country. Roughly stated, the quantity actually used varies from 5 to 18 bushels per acre. The average quantity of seed planted per acre in the United States was estimated several years ago by the Bureau of Crop Estimates at 8.6 bushels. As a rule, the smaller quantities are used by the southern truck grower, who is generally obliged to pay a high price for seed stock on account of his distance from the source of its production and the season of the year at which he has to have it delivered. In Aroostook County, Me., the common practice is to plant from 5 to 6 barrels of seed per acre, or from 825 to 990 pounds (13.7 to 16.5 bushels).

In order to afford a ready reference to the actual quantity of seed required to plant an acre with seed pieces of definite weights at a given distance between plants, the next table has been prepared to cover seed pieces ranging from half an ounce to two ounces in weight. It will be noted that plantings made at close intervals with seed pieces ranging from one and a quarter to two ounces

Number of bushels of potatoes required to plant an acre at different spacings with seed prices of various sizes.

Spacing of rows and seed pieces	Seed required, the average weight of seed pieces used being as given (bushels)						
	½ ounce	¾ ounce	1 ounce	1¼ ozs.	1½ ozs.	1¾ ozs.	2 ozs.
Rows 30 inches apart:							
8-inch spacing...	13.6	20.4	27.2	34.0	40.8	47.6	54.4
10-inch spacing...	10.9	16.3	21.8	27.3	32.6	38.1	43.6
12-inch spacing...	9.1	13.6	18.2	22.7	27.2	31.8	36.3
14-inch spacing...	7.8	11.7	15.6	19.4	23.3	27.2	31.1
16-inch spacing...	6.8	10.2	13.6	17.0	20.4	23.8	27.2
18-inch spacing...	6.0	9.1	12.1	15.1	18.2	21.2	24.2
24-inch spacing...	4.5	6.8	9.1	11.3	13.6	15.9	18.2
36-inch spacing...	3.0	4.5	6.0	7.5	9.1	10.6	12.1
Rows 32 inches apart:							
8-inch spacing...	12.8	19.1	25.5	31.9	38.3	44.7	51.1
10-inch spacing...	10.2	15.3	20.4	25.5	30.6	35.7	40.8
12-inch spacing...	8.5	12.8	17.0	21.3	25.6	29.8	34.0
14-inch spacing...	7.3	10.9	14.6	18.2	21.9	25.5	29.2
16-inch spacing...	6.4	9.6	12.8	16.0	19.2	22.4	25.6
18-inch spacing...	5.7	8.5	11.3	14.2	17.0	19.8	22.7
24-inch spacing...	4.3	6.4	8.5	10.6	12.7	14.9	17.0
36-inch spacing...	2.8	4.2	5.7	7.1	8.5	9.9	11.3
Rows 34 inches apart:							
8-inch spacing...	12.0	18.0	24.0	30.0	36.0	42.0	48.0
10-inch spacing...	9.6	14.4	19.2	24.0	28.8	33.6	38.4
12-inch spacing...	8.0	12.0	16.0	20.0	24.0	28.0	32.0
14-inch spacing...	6.9	10.3	13.7	17.1	20.6	24.0	27.4
16-inch spacing...	6.0	9.0	12.0	15.0	18.0	21.0	24.0
18-inch spacing...	5.3	8.0	10.7	13.3	16.0	18.7	21.4
24-inch spacing...	4.0	6.0	8.0	10.0	12.0	14.0	16.0
36-inch spacing...	2.5	3.8	5.0	6.3	7.6	8.8	10.1
Rows 36 inches apart:							
8-inch spacing...	11.3	17.0	22.7	28.4	34.0	39.7	45.4
10-inch spacing...	9.1	13.6	18.1	22.7	27.2	31.7	36.3
12-inch spacing...	7.6	11.3	15.1	18.9	22.7	26.5	30.2
14-inch spacing...	6.5	9.7	13.0	16.2	19.4	22.7	25.9
16-inch spacing...	5.7	8.5	11.3	14.2	17.0	19.8	22.7
18-inch spacing...	5.0	7.6	10.1	12.6	15.1	17.6	20.2
24-inch spacing...	3.8	5.7	7.6	9.5	11.3	13.2	15.1
36-inch spacing...	2.5	3.8	5.0	6.3	7.6	8.8	10.1
Rows 42 inches apart:							
18-inch spacing...	4.3	6.5	8.6	10.8	13.0	15.1	17.3
24-inch spacing...	3.2	4.9	6.5	8.1	9.7	11.3	13.0
30-inch spacing...	2.6	3.9	5.2	6.5	7.8	9.1	10.4
36-inch spacing...	2.2	3.2	4.3	5.4	6.5	7.6	8.6
Rows 48 inches apart:							
18-inch spacing...	3.8	5.7	7.6	9.5	11.3	13.2	15.1
24-inch spacing...	2.8	4.2	5.7	7.1	8.5	9.9	11.3
30-inch spacing...	2.3	3.4	4.5	5.7	6.8	7.9	9.1
36-inch spacing...	1.9	2.8	3.8	4.7	5.7	6.6	7.6

require quantities of seed very greatly in excess of those ordinarily used. On land well supplied with organic matter, an abundant supply of available plant food, and moisture, the use of large-sized pieces or whole tubers from one and a half to two ounces in weight will usually prove a profitable investment.

"**A safe general rule** to follow in planting potatoes is to increase or decrease the distance between the rows, as well as the hills, in accordance with the size of the seed piece used, the variety grown, the fertility of the soil, its moisture-holding capacity, and the average normal rainfall that may be expected when the plants are developing their tubers. The nearer the soil and weather conditions approach the ideal, the larger the seed piece and the closer the planting. Early-maturing varieties may be planted more closely than the late-maturing sorts, because the plants, as a rule, do not grow as large.

Fig. 31.—The old time way of planting potatoes. Portsmouth, Va.

"A study of the table discloses the fact that the quantity of seed required for planting an acre of potatoes with 2-ounce pieces at a spacing of 30 by 8 inches is more than 54 bushels. When the spacing in the row is doubled, that is, made 30 by 16 inches, only one-half this quantity will be required. It is believed that when seed pieces averaging 2 ounces in weight are used, a spacing of 12 to 14 inches may be expected to give better results than 10 to 12 inches. In other words, the spacing of the plants in the row is to a large extent governed by the size of the seed piece used."

Planting Methods.—The seed pieces may be either planted by hand or with a machine. In the South, where hand planting is more generally practised than in the North, the usual practice is to open up a furrow with a one or two-horse plow or middle buster, distribute and mix the fertilizer in the furrow, then drop the seed by hand (Fig. 31) and cover it with a plow. In the tule lands of the delta sections of the San Joaquin and Sacramento rivers near Stockton, California, seed is dropped by hand in every other furrow as the land is being plowed; while in certain parts of Michigan and Wisconsin, and probably other middle western states, some growers mark their land in both directions with a sled or other horse-drawn marker and then plant and cover the seed with a hand potato planter (Fig. 32). It should be stated that in some New England sections where but small acreages are grown the seed is dropped in open furrows in much the same manner as in the South.

Types of Planters.—Horse drawn machine planters are of two general types, *viz.,* the one-man or picker (Fig. 33), and the two-man type (Fig. 34). In the former, the seed pieces are picked up by forks attached to a revolving vertical disk which passes through a compartment containing the cut seed. The seed piece thus picked up by each fork is stripped off as it passes between two finger-like attachments and falls into the dropping tube. Accuracy in planting is largely dependent on the uniformity in size and shape of the seed pieces. Blocky shaped pieces are much more satisfactorily handled than wedge-shaped ones.

Fig. 32.—Planting potatoes with hand planters at Spooner, Wis.

The Two-Man Machine.—In the operation of the two-man planter the seed pieces, in one type, are raised singly from the hopper by a revolving cogged wheel set at an angle, and deposited in the pockets of a horizontally moving disk, which discharges the seed piece from each pocket as it passes over the dropping tube. The accuracy of this machine is dependent upon the ability of the second man, who sits in the rear, to see that each pocket has a seed piece and to remove any extra pieces that may be in others (Fig. 34). With a good man in the rear this machine will plant 100 per cent perfect; whereas with the picker type, if a fork failed to get a seed piece in its revolution through the supply chamber, or another fork spears two or more pieces, there is no one to correct these mechanical errors.

The Picker Planter.—The advantages of the picker type of planter are: (1) that it only requires one man to operate it; (2) that, on account of its automatic distribution of the seed, it is possible to drive the horses somewhat faster, thereby planting a larger acreage per day. Its disadvantage is that there is no one to correct the mechanical errors, such as have been previously mentioned.

Fig. 33.—A 2-row picker type of planter.

The Two Machines Compared.—Many growers feel that the slight inaccuracies of the picker planter are not of sufficient consequence to justify the additional cost of operating a two-man planter. Assuming that the picker type of planter drops the seed pieces 95 per cent perfect and that, as a result, the yield is cut, we will say 3 per cent, is this amount sufficient to pay for the extra man? The answer to such an inquiry is dependent upon two factors, (a) the yield produced; and (b) the price received for the crop. With a hundred bushel yield and a value of $1.00 per bushel, the net increase would be $3.00. As a two-man planter should average under fair working conditions about 4 acres per day, this would mean with present prices of labor from 75 cents to $1.00 extra cost per acre, but as the picker planter will plant, on an average, more land per day than the two-man planter, a further charge should be made against the latter. In the planting

FIG. 34.—Two-man type of planters. Courtesy of Bateman Mfg. Co., Grenloch, N. J.

of a 20-acre field of potatoes, let us assume that it required 4 days for the job with a picker planter and 5 days with a two-man planter, and that the cost of operating the one is $7.00 per day and $10.00 for the other. On this basis, the actual cost of planting an acre of potatoes with the picker type is $1.40, as against $2.50 for the two-man planter, or a difference of $1.10 per acre as an offset against the 3 bushel increase in yield.

It must be conceded, however, that 100 bushels per acre is rather a low yield, and that a 95 per cent stand is probably too high to represent a fair average. Suppose a yield of 200, 300, or 400 bushels were obtained from the picker-planted field; the profits from the use of the extra man are at once more than doubled, trebled, or quadrupled because the initial cost of planting remains the same; and the only additional cost is in the gathering, hauling and marketing of the extra bushels. Many fields, however, will not show over 90 per cent stand, and, if the seed is not fairly uniform in size and shape, the percentage of stand may be even

FIG. 35.—A good stand of Irish Cobbler potatoes. Aroostook County, Me., 1914.

less than this; thus we may have a much larger percentage of increase. In explanation of the calculation of a 3 per cent gain, instead of 5 per cent on a 95 per cent stand, it should be stated that plants adjacent to missing hills give an increased yield; it has therefore been thought desirable to only claim a 60 per cent increase or 3 instead of 5 per cent.

A Perfect Stand Desired.—The main, outstanding object for which the grower should strive is that of securing as nearly a perfect stand as it is possible to secure (Fig. 35). Maximum yields cannot be produced when there is a large percentage of missing plants (Fig. 36). Carelessly cut seed pieces, improperly handled seed or an imperfect planting machine all tend to reduce yield.

Effect of Bad Handling of Seed.—Poor seed is often the result of injuries to the tubers through rough handling. The practice of many seedsmen of shipping seed to their customers in sacks, instead of heavy pasteboard or wooden packages, is often responsible for much injury. This is well illustrated in figures 37 to 39, in which a sack and a pasteboard container are shown as is also the

FIG. 36.— A poor stand of potatoes due in large part to poor seed. Jerome, Ida.

condition of the stock as received from the express company. The reader can readily draw his own conclusions regarding the desirability of the two lots of seed.

There is every reason to believe that the same relative difference in the condition of the seed would have been noted if the shipment had been made by parcel post.

QUESTIONS ON THE TEXT

1. Is adaptation an important consideration in the selection of a variety? Why?
2. What is said regarding the Brown Beauty? Where is it grown?
3. Where is the White Rose grown?
4. Of what importance is good seed? Define good seed.
5. Is it desirable to plant the cull stock? Give reasons.

FIG. 37.—As received from the seedsman.

FIG. 38.—As received from the seedsman, except that the box had been opened after receival.

Fig. 39.—The lot on the left was shipped in the sack, while those on the right came in the pasteboard container.

6. How nearly does the certified seed now produced supply the demand.
7. Describe the method of greening or germinating seed tubers. Give object.
8. To what extent has the question of size of seed pieces been studied?
9. Is whole seed superior to cut seed? Can you give a reason?
10. What should constitute a fair basis of comparison as to the relative merits of different sizes of seed pieces?
11. What relation does the supply of plant food and moisture have to size of seed piece?
12. Where and under what conditions may whole tubers be used for seed purposes?
13. Why is the Charles Downing unsuited for planting whole?
14. How are seed potatoes usually cut?
15. Should automatic cutters be used? Why?
16. With what is it desirable to dust freshly cut seed, as an absorbent?
17. How should the cut seed be treated to preserve its vitality?
18. What factors should govern the rate or distance of planting?
19. What is the usual spacing in the United States?
20. At what distance are Irish Cobblers and Triumphs usually spaced in Maine?
21. What difference is noted for the Green Mountain?
22. How many seed pieces would it require to plant an acre if they were spaced 30 by 8 inches apart?
23. Where are the wider spacings practised? Why?
24. How many acres would the seed required for the closest spacing plant if used at the widest spacing?
25. What is the average amount of seed used per acre in the United States?
26. What is the average amount used per acre in Maine?
27. How is the seed usually planted?
28. In what sections of the country is hand planting still very largely practised?
29. Into what two classes or types are horse drawn planters divided?
30. Describe the mechanical operation of the picker type of planter. Give advantages and disadvantages.
31. Describe the operation of the two-man planter.
32. What is the approximate cost of planting an acre of potatoes with a one-row picker machine? With a two-man type of planter?
33. What is the main outstanding object for which the grower should strive in planting his crop? How secured?

QUESTIONS SUGGESTED BY THE TEXT

1. What varieties of potatoes are used for early planting in your region?
2. What ones are used for late planting?
3. What are the sources of these seed potatoes?
4. Is careful selection practised by local growers? Or are culls used by some for planting?
5. To what extent are greening and sprouting practised locally? For which crop?
6. Give the local practices regarding sizes of seed pieces and methods of cutting and treating seed.

7. What are the common local methods of planting? Give the distances?
8. What types of machine planters have you observed? What results?
9. What stands have you observed? Give percentages for best and poorest.
10. Assign some of your reasons for poor stands observed.

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CHAPTER VIII

THE CULTURAL CARE OF THE GROWING CROP

Systems of Culture.—There are two well recognized systems of potato culture in the United States commonly known as the ridge and level culture methods. In the choice of either of the systems the grower should be guided by his own environmental conditions.

Ridge Culture.—In the ridge culture method, the soil between the rows is loosened by some tillage implement, usually a riding cultivator (Fig. 40), and is then drawn or thrown up over or around the plants by a winged or disk horse-hoe (Fig. 41). In the

FIG. 40.—The earth is first loosened between the rows with a riding cultivator, after which it is moulded over the plants, before they have pushed through the surface, with a 2-row winged horse-hoe.

earlier stages of cultivation this process virtually consists in a tearing down and building up process. The ridge culture method is very generally practised in Maine, portions of New York and New Jersey, in the South, and in the irrigated regions of the West, with the exception of the Delta lands in the Stockton, California, district and the Clatskanie section in Oregon. Outside of the irrigated districts its practice is generally confined to regions where the rainfall is ample during the growing season, and also where high summer temperatures are not likely to occur.

Level Culture.—The level culture method implies a system of tillage that leaves the land practically level after each cultivation. As a rule most growers, at the last cultivation, adjust the cultivator teeth or shovels so as to throw the soil towards the plants. This is done to protect the tubers that are developing near the surface from being sunburned.

The system of culture to be practised should in a large measure, determine the depth at which the seed should be planted. In

Fig. 41.—A riding 2-row disk horse-hoe ridging or moulding the soil over the plants. This implement requires only one man to operate it.

level culture the seed piece should be planted deeper than in the ridge method. The deeper planting is necessary in order to protect the new tubers from light and sun heat, due to their formation too near the surface if planted shallow.

Tillage.—The term tillage, as herein used, relates solely to the cultivation of the crop after it is planted. The object of tillage is to stimulate the growth of the crop planted by destroying weeds and keeping the soil loose and friable. This, in turn, conserves moisture, aërates and sweetens the soil, and favors the growth of micro-organisms that aid in the decomposition of organic matter, as well as those that are concerned in the production of nitrate nitrogen. The more finely divided the soil particles are, the larger will be the amount of food made available to the plant. Good tillage, therefore, implies early, frequent, careful, and thorough cultivation of the crop, up to that stage of its growth when the injury to its root system is greater than the other benefits accruing therefrom. When this stage is reached tillage should be discontinued.

Pre-Germination Tillage.—The importance of cultivating the crop before the plants appear above ground cannot be over-

FIG. 42.—Pre-germination tillage of the potato crop with a weeder. Weed seeds may germinate but the seedlings are unable to establish themselves under this system of culture. Courtesy of the Bateman Manufacturing Co.

emphasized. The old practice, and one too frequently followed today, of allowing the crop to care for itself until the potato plants have appeared above ground in sufficient numbers to define the rows, is not to be recommended as an up-to-date method.

The implements commonly employed in pre-germination tillage when the level culture method is followed, are the spike-tooth or smoothing harrow, and the weeder (Fig. 42). Tillage with either of these implements is usually done by going lengthwise of the rows. The object of this early tillage is to maintain a surface soil mulch, thus conserving the moisture, and also to destroy germinating weed seeds. The significance of weed destruction at this early stage in their growth, before they have become deep-rooted, can be best understood by the statement that it frequently means the possibility of avoiding the necessity of hand-hoeing the crop later on. Cultivation with either or both of these implements may be continued without injury to the plants until they are well above ground, provided the teeth of the smoothing harrow are slanted backward so as to prevent deep penetration of the soil, with consequent injury to the potato stems. From one to two cultivations of this character are ordinarily sufficient, but, if frequent heavy rains occur during this period additional ones may be necessary.

FIG. 43.—Deep tillage between the rows prior to the appearance of the plants above ground.

The foregoing discussion of pre-germination tillage or cultivation applies to a large percentage of the potato acreage of the United States, but not to all of it. Aroostook County, Maine, furnishes a notable example of another type of pre-germination tillage. In this locality the growers practise the ridge system of culture; coupled with it they have adopted the method of moulding the soil over the plants prior to their appearance above ground. The grower, in this case, may entirely dispense with the spike-tooth harrow and the weeder; or he may use them once before beginning to mould or ridge the soil over the seed pieces. The course usually pursued is to cultivate the soil as deeply as practicable between the rows, and then follow this operation with a wing or disk potato hoe which draws or throws the soil over the row. In this section where potato growing is conducted on such a large scale, one seldom sees a one-horse cultivator, except in one of the final operations in which a one-horse potato hiller or wing shovel plow is used. The two-horse riding cultivator is used in loosening up the soil (Fig. 43) and a one-row or two-row walking or riding wing or disk potato hoe follows and ridges it up over the plants (Figs. 40 and 41). This operation may be repeated

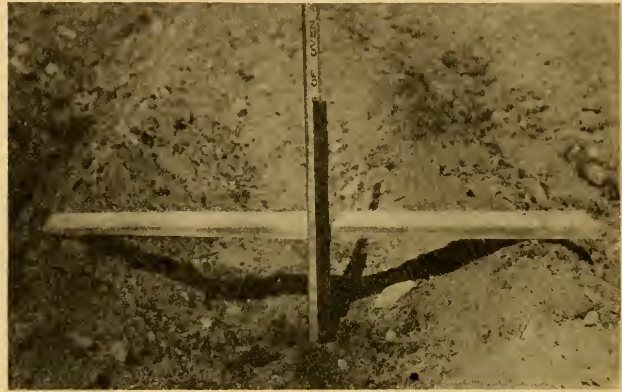

FIG. 44.—Normal height of ridges in Aroostook County, Me.

before the plants are finally allowed to break ground. This type of tillage is just as effective, if not more so, in the control of weed growth and the conservation of soil moisture, as is the harrow or the weeder. The height of the ridges is shown in figure 44.

Tillage after Germination.—In the level culture method, potato growers are generally agreed that the first cultivation of the crop after the plants appear above ground should be as deep and as close to the plants as it is possible to go. The two-horse riding cultivator is almost universally used in the northern commercial potato-producing sections (Fig. 45). In the South various implements including the riding cultivator are in use. The tendency however has been toward one-horse implements. A small one-horse turning plow is one of the implements commonly used by the southern truck grower in the cultivation of hoed crops, including the potato. Cultivation with the plow consists in throwing a light furrow away from the plants or toward them as the case may be, the object presumably being to bury weeds and loosen up the soil. The advisability of plowing a furrow away from the plants on each side of the row, leaving a narrow ridge of land, six to

FIG. 45.—First cultivation with the riding cultivator. Prior to this the surface of the ground was kept loose and the weeds destroyed by the use of the weeder or spike-tooth harrow. This field is being grown under the level culture system. Courtesy of the Bateman Manufacturing Co.

eight inches in width, standing up four or five inches above the bottom of the furrow exposed to the drying effects of the sun and wind, will hardly appeal to the reader as a sane cultural operation. If the object of such practice was to root-prune and check the growth of the potato plants, it might be regarded as a very commendable procedure; but as a stimulant to plant growth it should be classed as a highly undesirable cultural operation. The one-horse cultivator, when properly used, is just as effective an implement in loosening up the soil as the riding cultivator. In the level culture method little, if any, soil is thrown toward the plants until the final cultivation, when the outside shovels or cultivator teeth are set at an angle, so as to throw some soil toward the row. The number of cultivations that should be given is largely depen-

FIG. 46.—The last cultivation with the riding cultivator. After this the injury to the root system of the plant is normally greater than the benefits derived from loosening the soil. Courtesy of the Bateman Manufacturing Co.

dent on the character of the season and the soil. A safe general rule to follow is to till the crop as often as may be necessary to keep the surface loose and friable. This may be 3, 4, 5, 6, or more times.

After the first deep cultivation, the subsequent ones should be shallower and shallower and further and further away from the plants. The aim should be to cultivate as much of the intervening space between the rows as possible, without causing material injury to the roots of the plants.

Cultivation with level culture should cease when the plants are in bloom, or when the tubers get as large as a hen's egg. Whenever the root pruning becomes severe cultivation should cease.

In the case of ridge culture, cultivation may be continued a little later, because the roots of the plants are largely confined to the soil in the ridge, and the slight amount of tillage that is possible

FIG. 47.—A 4-inch artesian well near Palatka, Fla. Note volume and rate of flow.

in the centre of the row, does little if any injury. As a rule cultivation should cease when the plants are in full bloom or just passing out of it (Fig. 46).

Hand Hoeing.—In commercial potato-producing sections the crop is seldom hoed more than once; and in soil specially free from weeds, the hoe may not be used at all. Where potato growing is not strictly a commercial business, considerable hand hoeing is frequently done. Hand hoeing should, however, be regarded as too expensive a tillage practice to justify its extensive use. The grower should endeavor to destroy the most of the weeds in the

6

earlier stages of cultivation. In some sections, as in portions of Michigan and Wisconsin, the grower attempts to dispense with hand labor by check-rowing the field, so as to permit of cultivating the crop in both directions; but such wide spacing reduces the yield per acre and is not to be commended.

Special Cultural Features.—In the various production centres of the United States certain cultural practices are in vogue that are both interesting and instructive to those residing in other sections of the country. The Hastings district in Florida, for ex-

Fig. 48.—One row omitted between raised beds for irrigation furrow.

ample, is of interest from the standpoint of its irrigation practice and system of growing the potato crop on raised beds. The irrigation water in this district is obtained from artesian wells. (Figs. 47 to 50). Artesian water is usually found at from 150 to 175 feet, and throughout the whole area the flow varies from a few feet to as much as 40 feet above the sea level. Around Hastings, where the land elevation is only about eight feet, many of the wells have a flow pressure of about twelve and a half pounds per square inch. A four-inch well ordinarily furnishes sufficient water to irrigate a 40-acre tract, and a six-inch well easily cares for 60 acres or more. Tests made on the rate of flow of a two-inch well indicated a capacity of 80 gallons per minute. The water is more or less strongly impregnated with sulfur, giving it a distinctly hydrogen sulfide smell and taste. It emerges from the well at a temperature of 70 degrees F. The irrigation water is applied to the growing crops by means of open ditches or dead furrows between the raised beds on which the crop is grown (Fig. 49). The water spreads out over the somewhat impervious clay sub-soil with which most of the land is underlaid, and is taken up by capillary action. The crop is grown on raised beds of from 8 to 16 rows in width,

FG. 49.—Irrigation furrow or ditch full of water.

with deep dead furrows separating the beds; the dead furrows serving as irrigation channels or ditches for the distribution of the water. Drainage ditches have to be provided in order to carry off the waste water, as well as to take care of the heavy rainfalls which not infrequently occur in this region (Fig. 50). The drainage ditch may be closed while irrigation is in progress, but is opened up immediately thereafter, the aim being to remove the surplus or waste water as quickly as possible. Cultivation should follow each irrigation in order to keep the soil loose and well aërated. An implement known locally in the Hastings district as a scooter is rather commonly employed in the later cultivation to loosen up the soil in the bottom of the furrow.

In the Beaufort section of South Carolina, as well as in most portions of Southern Alabama, Mississippi, and Louisiana, the practice of planting the crop on well defined ridges is quite common. These ridges are formed by back-furrowing the land and then opening up the ridge with a middle-buster plow; the seed pieces being dropped in the furrow thus formed and covered with the middle buster. Where high ridging is practiced (Fig. 51) or where two rows, spaced about 20 inches apart, are planted on a ridge, the distance from centre to centre of the ridges varies from three and a half to four feet apart (Fig. 52). In lower ridging the spacing is usually about three feet apart. The practice of planting two rows to a ridge with a narrow spacing between, has

Fig. 50.—A large drainage ditch near Vero, Fla. showing typical vegetation of the region.

only been observed by the writer in the Beaufort, S. C. section, and there on only a single farm (Fig. 51).

In all irrigated sections of the West, outside of the Stockton district in California and that of a restricted area around Clatskanie in Oregon the usual method of applying water to the crop is to run it down the furrows between the rows. Some growers irrigate in every furrow, while others only allow the water to flow in every other row. The first method is more commonly practised. Irrigation projects are found in all states west of Minnesota, or in North and South Dakota, Nebraska, Colorado, Wyoming, Montana, Utah, Idaho, Nevada, Oregon, Washington, California, Arizona and New Mexico.

The usual procedure in irrigating the potato crop is to apply water only when necessary to keep the plants in an active stage of growth. Most growers prefer to withhold the first irrigation until the tubers have begun to form; but this is not always possible, as there are seasons in which the moisture in the soil is insufficient to germinate the seed pieces. Under such circumstances the grower has no other alternative than to irrigate. This is known as "irrigating up." Other seasons occur in which, through lack of winter snows or rains and the prevalence of drying winds in the spring, the soil moisture is so deficient that it becomes necessary

Fig. 51.—Single row ridging in the South. A roller is often used to firm the loose soil and increase capillary movement of moisture.

to irrigate before preparing the land for planting. Such practices are of course only possible on irrigation projects that furnish water for early irrigation. Usually 3 to 4 irrigations throughout the growing season are sufficient to make a good crop. Occasionally, the crop may be made with two applications of water; in unfavorable seasons, that is when there is practically no precipitation or an unusual amount of windy weather, 6 or 8 may be necessary. The aim of the irrigator should be to supply sufficient water at all times to keep the plant in a healthy growing condition throughout the growing season. Irrigation should cease from 4 to 6 weeks before the harvesting period in order to ripen the crop. Some growers do not observe this practice, preferring to sacrifice the quality of the crop for the sake of a greater tonnage. The result of continuing irrigation almost up to the harvesting period is the production of overgrown tubers containing a high percentage of water. Such tubers, on account of their unripe condition, are more easily injured in harvesting, do not keep as well in storage, and are not as satisfactory for table or seed purposes.

Fig. 52.—Double row ridging in the Beaufort, S. C., district.

The Stockton and Clatskanie Districts.—Inasmuch as the Stockton and the Clatskanie districts are practically identical so far as their management is concerned, the description of the methods pursued in the former region may be regarded as applying to the latter district. As an aid to a clearer understanding of the method of applying water to the crop in the Stockton district, it seems desirable to give a brief description of the character of the soil and its physiography. This district embraces what is known as the delta lands of the San Joaquin and Sacramento rivers, commonly referred to in that section as the tule lands, (Fig. 53).

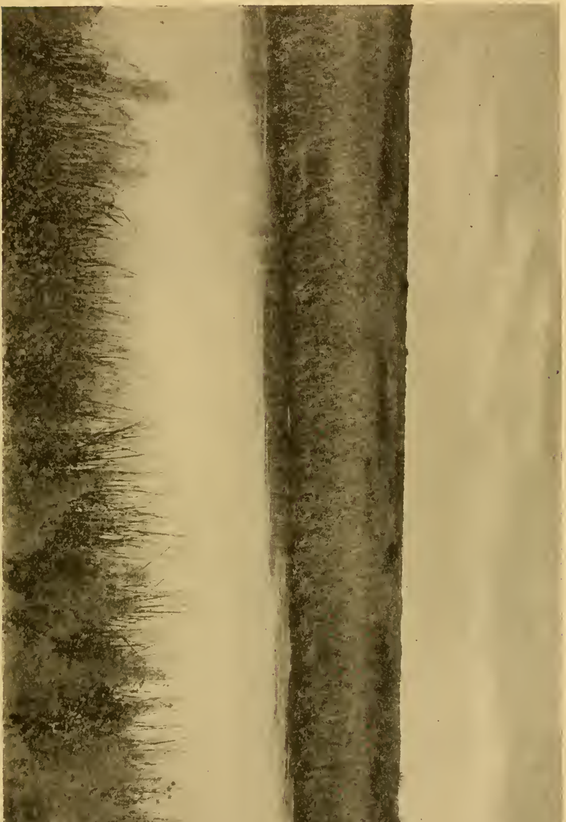

Fig. 53.—Characteristic appearance of the unreclaimed tule land in the delta sections of the San Joaquin and Sacramento Rivers.

"Tule" is the Mexican name of a large bulrush which grows abundantly on the unreclaimed portion of this land. The tule lands are almost entirely of organic origin. They are in reality reclaimed peat bogs. The usual procedure in reclaiming such land is to build a rather high earthen levee around a considerable tract of land by means of a large dredge (Fig. 54). When the levee is completed (Fig. 55), the drainage ditches are cut through

Fig. 54.—The first step in the reclamation of tule land is that of constructing a levee around a tract of land. The soil is scooped up by large scoops operated by a floating derrick.

the tract and, at some convenient point, a large centrifugal pump is installed on the levee. The operation of this pump by electricity or other motive power soon tends to lower the water table in the inclosed area. The water lifted by the centrifugal pump is discharged, over the levee, into the river or canal opened up by the removal of soil for the construction of the levee. As soon as the soil in the tract is sufficiently dry to work it is plowed. Usually, the grower plows the land in the autumn or early winter months, and fits it in the early spring. When the root-filled soil has been put in reasonably good shape it is ready for the replowing, necessi-

Fig. 55.—The levee in the raw state; as the water table is lowered the soil subsides and requires further building. Many of these levees are later converted into roadways, thus performing a dual service.

tated by practice, in this section, of planting the seed pieces in every other furrow as the land is being replowed. The peculiar character of this soil, it is claimed, precludes the use of the potato planter. The real facts are that, owing to the porous character of the soil, the high evaporation of moisture during the growing season, and the high temperature of the upper layer of soil during the day, the potato plant succeeds better when the seed pieces are planted at a depth of from 6 to 8 inches. The present types of potato planters are not constructed to plant the seed piece much over 4 inches in depth. Irrigation is accomplished by cutting narrow ditches of about 30 inches in depth and from 60 to 75 feet apart. These lateral ditches are usually cut between the potato rows after the plants are well above ground. The skill and precision displayed in cutting these ditches and disposing of the soil, with but little disturbance of the plants in the adjacent rows, seems to be developed to a high degree in the Japanese and Chinese farmers and laborers, by whom the larger proportion of the crop in this region is grown. After the lateral ditches are cut and the plants are in need of moisture, the water for irrigation purposes is either siphoned out of the river proper, or canals; or it is admitted through sluice gates into the large distributing ditches which, in turn, supply the laterals cut between the potato rows. The laterals are kept full until the moisture has transfused throughout the entire intervening spaces or strips of land, after which it is drawn off in order to keep the soil sweet. This process is repeated as often as may be necessary throughout the growing season.

QUESTIONS ON THE TEXT

1. How many well recognized systems of potato culture are in vogue in the United States? Name and describe them.
2. What is meant by the term tillage?
3. What is the object of pre-germination tillage? What implements are used for it?
4. What is the usual level culture tillage practice after the plants appear above ground?
5. What implement does the southern grower frequently use?
6. What objection is there to the use of the one-horse plow?
7. In level culture, what is the customary practice when giving the crop its last cultivation?
8. When should cultivation of the crop cease?
9. To what extent should hand hoeing be practised in commercial potato production?
10. How does the grower avoid hand hoeing in certain parts of Michigan and Wisconsin?

11. What cultural practices obtain in the Hastings district in Florida?
12. What is the source of the irrigation water in this district?
13. How many acres will a four-inch well irrigate?
14. How is the water applied to the growing crop?
15. What use does the grower make of the implement known as the scooter?
16. What special system of culture is found in the Beaufort district of South Carolina?
17. How is water applied to the potato crop in the West?
18. Describe the practice known as "irrigating up."
19. How often should the crop be irrigated?
20. What effect has late irrigation upon the quality of the crop?
21. What is the soil formation in the Stockton district?
22. How is it reclaimed?
23. How is the crop planted?
24. How is the irrigation water applied?
25. By whom is a large part of the crop grown?

QUESTIONS SUGGESTED BY THE TEXT

1. Describe the most common local systems of culture.
2. What implements are common in this work?
3. How much pre-germination tillage is practised by your local growers?
4. Is irrigation in any form used by your growers? Describe it.

CHAPTER IX

POTATO PRODUCTION IN THE SOUTH

In many respects the production of potatoes in the South is quite distinct from that of the North and West. The chief points of difference are first, that the potato is very largely grown in the South as an early or truck crop; second, that there are three rather distinct crop periods, *viz.*: the early or truck crop, the late or main crop, and the fall crop. A full discussion of these three crops is presented in a later portion of this chapter.

Extent and Importance of the Crop.—The usual procedure in judging the importance of any crop is by comparing production in any given locality or region with that of other sections. Fortunately such a comparison is made possible through the geographical division of the United States, by the Bureau of Crop Estimates, into three great regions, known as the "northern," "far west," and "southern." The states embraced in each of these areas are given in next table. This shows that the northern division includes 21 states, far west 11, and the southern 16.

Distribution by Sections.—The December 1st report of the Bureau of Crop Estimates shows a total production, in the United States, of 428,368,000 bushels of potatoes. Of this amount the 21 northern states produced 304,523,000 bushels, the 11 far western states 59,275,000 bushels, and the 16 southern states 64,570,000 bushels. Expressed in percentages, the northern group of states produced 71.09 per cent; the far-western 13.84 per cent; and the southern group 15.08 per cent. It is thus seen that the southern potato crop represents but a little over one-seventh of the entire crop of the United States.

The Money Value.—If, however, we consider the crop from the standpoint of its money value to the producer, which, after all, is the only proper basis of comparison, it assumes an entirely different degree of importance, because the early truck crop of the South usually sells for a much higher price than that of the late crop in the North. This is due to the fact that the northern or western consumer is willing to pay a considerable premium for new potatoes over that for old stock. Hence, it can be readily seen that the new potato crop from the South has a financial value out of all proportion to its volume. There are seasons, of course, in which the May to August prices for southern stock rule low. This is, as a rule, due to either one of two conditions, *viz.*, a large holdover stock of the northern crop, or excessive production in the South, which tends to depress the market for both the old as well as the new stock. Such a condition occurred during the Spring of 1918, when the growers in northern Florida were obliged to dispose of a considerable portion of their crop at an actual loss. For this reason, the production of early potatoes in the South is a somewhat uncertain proposition, because the grower

List of States Included in the Three Geographical Areas

Northern		Far western	Southern	
Maine	Illinois	Montana	Delaware	Georgia
New Hampshire	Michigan	Wyoming	Maryland	Florida
Vermont	Wisconsin	Colorado	Virginia	Alabama
Massachusetts	Minnesota	New Mexico	West Virginia	Mississippi
Rhode Island	Iowa	Arizona	North Carolina	Louisiana
Connecticut	Missouri	Utah	South Carolina	Texas
New York	North Dakota	Nevada	Tennessee	Oklahoma
New Jersey	South Dakota	Idaho	Kentucky	Arkansas
Pennsylvania	Nebraska	Washington		
Ohio	Kansas	Oregon		
Indiana		California		

has comparatively little leeway in the marketing of his crop. If the crop is a normal one, he must market it within a relatively short time or else he will be in competition with growers farther north; then too, it must be harvested before a certain period, else crops that are to succeed it will suffer as a result of not having entire use of the land. There is yet another reason why the harvesting of the southern crop cannot be very greatly delayed; that is, that it is not, as a rule, safe to allow the crop to remain in the ground for any considerable period after it is ripe, owing to danger from tuber decay. This applies more particularly to the southern tier of states.

Relative Importance of the Three Crops.—A fairly good idea of the relative importance of the early crop to that of the late or main crop, and the fall crop which are here considered together, may be obtained from a study of the data, published by the

Bureau of Crop Estimates, in the monthly report for May, 1918, in which the disposal of the crop is given by months for each of the 16 states. These data which are assembled in the next table, afford a very good index to the relative importance of the early crop in each of the States. It is admitted that these figures are approximate, rather than actual; the disposal of an early crop

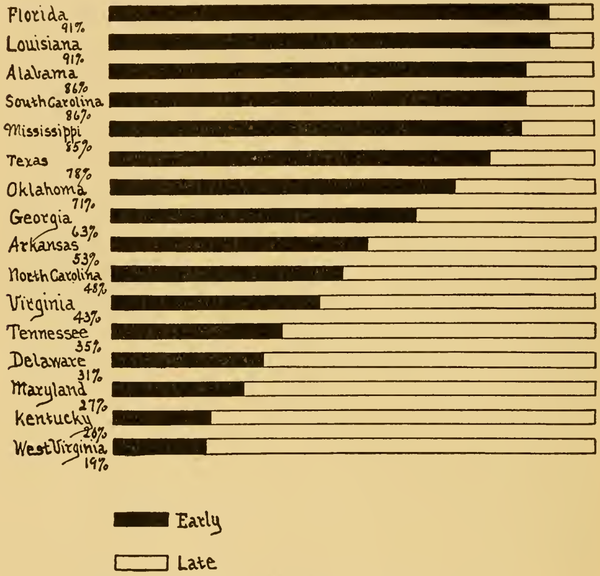

FIG. 56.—Approximate per cent marketed as an early crop, 1918.

may be hastened or delayed according to whether the supply is short or ample, or the market active or sluggish. It is believed, however, that these data are of value in that they afford a very fair index of the volume of the early crop, and the period of time during which it is normally marketed in each state. The per cent given represents that portion of the crop harvested and marketed, during the periods mentioned. It is conceivable that some may disagree with the arbitrary time division that, of necessity, had to be made in the preparation of these data, but it is believed that they are approximately correct:

Owing to the fact that there are no data bearing upon the extent of the late or main crop, and the fall crop production in the South, the only possible separation of the crops on the production basis is that of comparing the early with that of the other two crops.

The significance of the data presented in the foregoing table may be more readily grasped by a study of figure 56 in which

Approximate per cent Marketed as an Early Crop as Distinguished from Late Crop.

State	Date Marketed	Per cent	State	Date Marketed	Per cent
Alabama . . .	Apr. to Aug. 31	86	Mississippi . .	Apr. to Aug. 31	85
Arkansas . . .	May to " "	53	North Car. . .	May to " "	48
Delaware . . .	June to " "	31	Oklahoma . .	May to " "	71
Florida	Feb. to " "	93	South Car. . .	Apr. to " "	86
Georgia	May to " "	63	Tennessee . .	May to " "	35
Kentucky . .	June to " "	20	Texas	Apr. to " "	78
Louisiana . . .	Apr. to " "	91	Virginia	May to " "	43
Maryland . .	June to " "	27	West Virginia	June to " "	19

these data are graphically presented or visualized. It is apparent from this graph that the early crop is of less relative importance to the other two crops in the northern tier of the southern group of states than in the strictly southern ones.

The fluctuation in total production of the sixteen states and the farm value of the crops during the five-year period 1914-1918 inclusive, as shown in figure 57, is especially interesting in that it covers the period in which the late World War occurred. These data are indicative of the expansive flexibility of the potato industry in the South whenever the necessity for more food arises, or whenever a partial crop failure in the North assures a good market for the early crop.

A. THE EARLY OR TRUCK CROP

As has been previously shown, the early crop of potatoes in the South is by far the most important part of the Irish potato industry of that region. It is grown, as a rule, in what might be designated as intensive potato-producing centres. These centres of production usually owe their origin to certain favorable conditions for growing and shipping early potatoes. Concentration of the industry also affords other benefits to the growers in that it brings the buyers to their doors. This insures competitive buying and, in consequence, a better price to the grower. Active buying is of greater importance to the southern grower than to the northern one, because he is obliged to market his early crop within

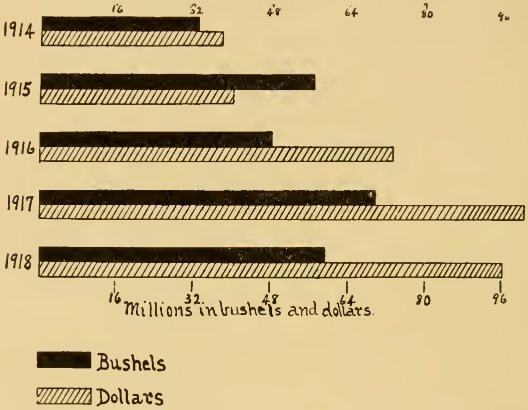

FIG. 57.—Average annual production in bushels and value of same for the sixteen southern states during the years 1914 to 1918.

a comparatively short time after it reaches marketable size. It is not feasible to store it, as is the case with the northern crop. In addition to this, the southern crop must be dug in order to make the land available for the ensuing crops, such as corn, cowpeas, etc. The conditions that are generally regarded as favorable for the production of an early crop are: (1) a light sandy loam soil, possessing good drainage and not subject to drought; (2) good shipping facilities, either by rail or boat; (3) plenty of farm labor; (4) a short haul to shipping point.

Commercial Production Centres.—There are a number of well developed commercial potato-production centres in the South. The more widely known centres or districts are Hastings, Fla.; Beaufort and Charleston, S. C.; Beaufort, N. C.; Norfolk and the

Eastern Shore, Va.; the southern portion of the Maryland peninsula; Louisville, Ky.; Columbia, Tenn.; Fort Smith, Ark.; Fort Gibson, Okla.; Eagle River, Wharton and Brownsville, Tex., and Alexandria, and Bayou La Fourche, La. These localities have developed into relatively large producing centres because the necessary elements of success were present. The only exception that might be taken to the preceding statement is with respect to the Brownsville district, which has only come into prominence within the past year or two. A few of the many elements essential to the development of any large industry, and particularly of a relatively bulky commodity are good shipping facilities and a favorable soil and climate. Then, too, the larger the production in any given locality the more likely it is to attract a greater number of buyers. In addition to this, is the application of good business methods in the growing and marketing of the crop. Finally, the growers themselves are largely responsible for the success or failure of potato-production centers. Many new localities engage in potato production in a more or less extensive manner each year; but few of them persist for any length of time, for the simple reason that some conditions are not conducive to the development of a successful industry.

Soils.—If one were to study the soil types in each of the production areas mentioned, they would be found to be of a more or less similar character in that most of them are of a warm sandy nature. Those in the Atlantic Coastal Plain area consist very largely of the Norfolk sandy loam series. In the Hastings district in Florida, the best potato soil is known as the Bladen fine sand or sandy loam series. The Eagle Lake and Wharton soil types are of a distinctly sandy nature, and are for the most part of alluvial origin. Those of the Fort Gibson and Fort Smith sections are largely river bottom soils of the Grand and Arkansas Rivers, consisting of a sandy loam sometimes bordering on a heavy loam soil. Those of Alexandria, in Louisiana, and Louisville, in Kentucky, are also of a sandy character and easily handled. They are soils that warm up quickly in the late winter or early spring, that respond generously to liberal fertilization and good cultural treatment; and are well adapted to the production of early crops.

Varieties Grown.—The varieties of potatoes grown for the early crop in the South are the Irish Cobbler (Figs. 237, 238).

Triumph (Figs. 239, 240), and Spaulding No. 4 (Rose No. 4) (Fig. 246). The Irish Cobbler is most extensively grown in the Atlantic Coast States from Georgia to Delaware, and the Louisville district, in Kentucky. It is also grown to some extent in most of the other states. The Triumph is grown most extensively in southern Florida, Alabama, Mississippi, Louisiana, Texas, Oklahoma, Arkansas and Tennessee. Spaulding No. 4 is almost entirely restricted to the north central and northeastern portion of Florida. It is grown practically to the exclusion of all other varieties in the Hastings district.

Source of Seed Supply.—Outside of the relatively small amount of second crop seed produced in certain localities in the South, the southern grower is wholly dependent upon northern grown seed stock for the planting of his early crop. The potato growers of northern Maine furnish a large portion of the Irish Cobbler and Spaulding No. 4 seed stock and lesser amounts of the Triumph. Wisconsin, Minnesota and Nebraska supply a large share of the Triumph seed used in the Triumph-producing areas of the South. Usually the grower purchases his seed from his local commission man or seed dealer. In the extreme South, delivery of northern grown stock must be made during December and January, thus necessitating its shipment shortly after it is harvested. In the Norfolk and Eastern Shore of Virginia and Maryland district, deliveries are made during the latter part of January, and extending into March. The seed stock for this area is, therefore, purchased in the North, with the understanding that it must be held there until the time mentioned. This necessitates its shipment at a period of the year when extreme cold weather is quite apt to prevail, thus running the risk of having it frozen or overheated during transit. The overheating of seed enroute is likely to occur when heavy firing is necessary to prevent frost getting into the car. It has always seemed to the writer that in order to avoid these risks, as well as that of delays in delivery due to weather exigencies and car shortage, the southern grower could well afford to provide suitable storage houses or warehouses for the holding of the seed throughout the late autumn and early winter months. If such provision were made, the southern grower could purchase his seed stock subject to fall delivery, and thereby secure it at a much more favorable price than that demanded for winter delivery. It is further believed that the Southern grower could effect a very considerable saving in the purchase of his seed stock by the growers organizing in his section into a coöperative purchasing association, and sending one or more representative growers to the seed producing centres during the growing season, with instructions to arrange for the purchase of the required amount of seed from the healthiest and best looking fields. This would guarantee them high quality seed and at the same time assure an early and prompt delivery in the fall. At the present time, the difference in cost per sack between autumn and winter delivery averages about $1.00. A wider margin of difference than this obtains when shipments are made subject to the grower's or dealer's risk.

*Approximate Dates of Planting Early, Late or Main, Second, and Fall Crop Potatoes in the South.**

State	Date of planting early crop	Date of planting late or main crop	Date of planting second and fall crop
Alabama	Jan. 15 to Feb. 15		Aug. 15 to Sep. 15
Arkansas	Feb. 15 to Mar. 15		July 15 to Aug. 15
Delaware	Mar. 20 to April 20	April 25 to May 25	June 25 to July 20
Florida	Nov. 20 to Mar. 1		Sep. 1 to Oct. 10
Georgia	Jan. 15 to Feb. 15	April 25 to May 25	Aug. 1 to Sep. 1
Kentucky	Mar. 1 to April 10	April 15 to May 20	July 1 to July 25
Louisiana	Jan. 15 to March 10		Aug. 15 to Sep. 1
Maryland	Mar. 1 to April 25	April 25 to June 5	June 20 to July 20
Mississippi	Jan. 15 to Feb. 25		Aug. 15 to Sep. 1
North Carolina	Feb. 15 to Mar. 25	April 25 to May 30	July 10 to Aug. 10
Oklahoma	Feb. 15 to Mar. 20		June 15 to July 10
South Carolina	Feb. 1 to Mar. 15	April 20 to May 25	July 15 to Aug. 20
Tennessee	Mar. 1 to April 10	April 15 to May 20	July 10 to Aug. 1
Texas	Jan. 1 to Mar. 15	April 1 to May 15	July 1 to Sep. 1
Virginia	Feb. 15 to April 1	April 20 to May 25	July 1 to Aug. 10
West Virginia	Mar. 15 to April 30	April 25 to May 30	June 25 to July 10

* These data are based, in part, upon information obtained from the U. S. Bureau of Crop Estimates, and partly from the writer's personal observation or knowledge of dates of planting in many of the states.

Date of Planting.—The dates of planting in the table are intended to represent the approximate period in which the early, late, and fall crops are planted. The data for the late and fall crops being presented in connection with that of the early in order that the three sets of dates could be easily compared. In all instances the earliest date for the early crops and the latest date for the fall crop refers to the southern or warmer portion of the state, while the reverse dates apply to the northern portion of it. For example, the date of planting the early crop in Texas varies from January 1st to March 15th; while the fall crop planting extends from July 1st to September 1st.

It should be borne in mind that the dates given are not intended to be taken too literally. They simply represent, as stated, the approximate range of time in which the bulk of the planting of each crop occurs. It is quite possible that some particularly well favored locality could plant earlier than the earliest date given, while in other cases later planting than the last date given might be necessary.

Early Marketing.—In the production of early potatoes in the South the object of the grower is to bring his crop to marketable maturity as quickly as possible. To do this, it is necessary to plant the seed as early as the soil and the climatic conditions will permit. On certain farms, or in some limited areas as, for example, Federal Point in the Hastings district, Florida, the crop may be planted from one to two weeks earlier than the rest of the section. At Federal Point planting very often begins in the latter part of December, whereas in the district as a whole, it is usually not well under way until the middle of January. As might be expected the crop is frequently injured by late spring frosts. Occasionally the frost injury to the plants is severe enough to cause a material reduction in yield; and on rather rare occasions it may actually kill the plants. Light frosts simply retard the maturity the North.

B. LATE OR MAIN CROP POTATOES

Generally speaking, late or main crop potato production in the South is confined to those regions or localities in which it is not possible to produce an early crop. For example, in Maryland, Virginia, West Virginia, North and South Carolina, Georgia, Tennessee, and Kentucky, late potatoes are grown in the mountainous sections where the climatic conditions approach those in the north.

Late or Main Crop Potatoes Defined.—In order to avoid the possibility of confusion in the mind of anyone concerning what is meant by late or main crop potatoes, the following explanation is offered. Late or main crop varieties are those that require a longer season in which to reach maturity; in other words they are late maturing varieties and as such are unsuited for early crop production. They are normally planted after all danger from late spring frosts has passed. The crop is planted, cared for, and harvested in practically the same manner as that in the North, and like the northern crop is intended for fall and winter consumption.

Soil.—A greater variety of soil may be used in the growing of late crop potatoes because the element of earliness is not an important consideration; hence heavier and naturally colder soils are more satisfactory than the lighter and warmer ones provided they are well drained.

Varieties Grown.—The varieties most commonly grown for the late crop are those belonging to the Green Mountain and Rural groups of potatoes, such as the Green Mountain, (Fig. 259, Chap. 22). Gold Coin, Delaware and Snow, in the first group and the Rural New Yorker No. 2, (Fig. 261, Chap. 22). Carman No. 3, Sir Walter Raleigh and Russet Rural in the second group. Other varieties such as the Peerless, Mammoth White Pearl, White Star are grown to a much lesser extent. The Early Rose and Early Ohio are grown to some extent for late crop use.

Importance of the Crop.—As no attempt has ever been made by the Bureau of Crop Estimates, the U. S. Census, or any other agency to distinguish between the late crop and the fall crop there is no way of determining what proportion of the total production of these two crops is represented by the late crop. It is safe to say, however, that in the states specifically mentioned the proportion is strongly in favor of the late crop.

C. FALL CROP POTATOES

The chief points of difference between the late or main crop and the fall crop of potatoes is that the latter is planted in midsummer or later and is intended to mature during the late fall months. Fall crop potatoes really consist of two rather distinct crops, *viz.*: the fall crop proper and second crop potatoes. The first crop consists of later maturing varieties intended for winter consumption; while the second crop consists of early varieties planted, as a rule, after the first crop is harvested. The crop produced from this second planting is generally used as seed stock for the early crop of the ensuing year; in fact it might be stated that, when grown on a commercial basis, the production of second crop seed is usually the sole motive of the grower.

Fall Crop Proper.—Fall crop potatoes are usually only grown in those sections of the South in which the growing season is long enough to produce two crops. Or, to state the proposition another way—where early crop potatoes are produced. Exceptions to this statement may be cited as, for example, certain portions of Virginia, Maryland, and District of Columbia, which are in no sense early or truck crop potato sections.

Fall Varieties Grown.—The variety that is almost universally grown as a fall crop potato is variously known under the names of McCormick (Fig. 266), German Peachblow, Lookout Mountain, Hoosier, and Blush depending upon the locality of the South in which it is grown. It is a strong-growing, late-maturing variety which possesses an unusual degree of heat and drought resistance which enables it to thrive under climatic conditions that are oftentimes quite injurious to the other varieties. Owing to these qualities it is the surest cropper of any fall variety now known in the South. A sport of this variety known as the White McCormick has found much favor with Maryland growers, and its popularity seems to be spreading to other southern states. As its name implies it is a white-skinned potato, with fewer and shallower eyes than the true McCormick which has numerous and rather deep eyes. It is also of better table quality, and seems to be fully as resistant to heat and drought as the true McCormick.

Other varieties that may be grown for a fall crop are the same as those mentioned for the late crop, *viz.*, the various varieties belonging to the Green Mountain and the Rural groups, the Peerless, White Star, Burbank, and in some few localities the Early Rose and the Early Ohio.

The McCormick and White McCormick varieties possess other characteristics than those of resistance to heat and drought and sure croppers, which make them still more desirable to the southern grower. These characteristics are their long-keeping qualities and their slowness to germinate or sprout in the spring. Many growers are able to keep them from germinating seriously until planting time the ensuing summer, without resorting to putting them in cold storage. As few of the growers are provided with good storage it is readily seen that this is a very desirable quality. When the other varieties are used, the grower is obliged to procure northern grown seed of the preceding season's crop and hold it over in some suitable storage house, until shortly before planting time when it is required for use. This, necessarily, increases the cost of the seed to the grower.

Second Crop Potatoes.—Under this division of potato production is included all early varieties that are primarily grown as a second crop, or late crop, for the production of seed potatoes intended for use in the planting of the ensuing year's early or truck crop.

Strictly speaking, the only genuine second crop potatoes grown in the United States are those produced in regions where the Triumph is the leading early variety; as, for example, in the Fort Smith and Fort Gibson districts in Arkansas and Oklahoma, where the tubers from the early crop are used for planting the second crop. This, in the writer's judgment, is true second crop potato production.

In the Louisville, Kentucky, and the Norfolk and Eastern Shore of Virginia and Maryland districts, as well as certain sections of North and South Carolina where the Irish Cobbler is grown as an early crop, it is not possible to use seed from this crop for the planting of the second crop, because the period between the harvesting of the first crop and the planting of the second crop is not sufficiently long, and what is still more important, the Irish Cobbler variety apparently requires a longer rest period than the Triumph. The seed used has to be imported from the North, and consists of the preceding year's late or main crop, which has been held over in cold storage during the warm weather of late spring and early summer. In the Louisville district second crop seed is held over in cold storage.

The second crop, whether in the Fort Smith or the Louisville districts, is usually grown on land that has produced an early crop; it is generally planted in the same rows without the application of any additional fertilizer.

Second Crop Cultural Practices.—In view of the varied methods in vogue in the handling of the tubers from the first crop, during the interim between harvesting the one and planting the other, it seems desirable to briefly consider the six plans. For the sake of convenience, these practices are numbered.

Practice No. 1.—The small or unsalable potatoes, really the culls, and the few marketable tubers overlooked by the pickers, are thrown back into the furrow opened up by the plow in turning out the first crop, or in the freshly opened furrow if the elevator digger is used. The aim of the grower is to grow the second crop in the same drill row as the first one. This method is followed in order to give the second crop plants the opportunity of using up whatever residual plant food there may be left in the soil from the first application of commercial fertilizers. Sometimes the newly harvested tubers are planted in some previously prepared land on which potatoes had not been grown during that current season. The practice of planting back in the same furrows as soon as the first crop is removed has the advantage of minimizing labor; but the disadvantages of a slow and imperfect germination, and the inevitable weed growth that is sure to take possession of the soil before the seed germinates, are factors that need to be carefully considered.

Practice No. 2.—This practice differs from the foregoing in that, instead of planting the culls where they are to grow immediately after harvesting them, they are stored in trenches to a depth of from 4 to 6 inches and covered with a heavy layer of soil. The trench should be located on well drained land. It may be opened with a plow, and, after the trench is filled with potatoes, the same implement may be used in covering the seed. They are left in this condition until wanted for planting, which would be approximately from three to five weeks; then the trench is opened and the potatoes sorted over. Only those which are showing sprouts are selected for seed purposes, thus insuring a quick germination and a good stand of plants. The disadvantage of this practice is that, when sufficiently heavy rains occur to soak the soil surrounding the potatoes and this is followed by hot weather, heavy losses from tuber decay may occur. This condition could be obviated by covering the trench so as to shed water, or by burying the potatoes on raised beds, which could be covered if necessary. Nothing but sound stock should be handled in this manner.

Practice No. 3.—This method differs from 1 and 2 in that the tubers are spread out on the ground in some shaded place, as under a building, in a shed, or under a tree, and allowed to turn green for from three to six weeks before planting. This allows the grower as in 2 to select for seed purposes only those tubers which show signs of sprouting.

Practice No. 4.—This method usually differs from No. 3 in but one detail, which is that the tubers are covered with a layer of straw, hay, or other coarse material, which partially protects them from the light and, to some extent, governs loss of moisture. Some growers go a step farther in this method by occasionally moistening the straw covering.

Practice No. 5.—This practice is, so far as known, a comparatively new one. It consists in immediately placing the seed potatoes from the first crop in cold storage, where they are held at a temperature of 32 degrees F. from four to five weeks, after which they are taken out and allowed to warm up for a few days before planting. The effect of low temperature on the new potato is to shorten the rest period and thus hasten germination.

Practice No. 6.—This method is one which may be practiced in connection with any of the preceding ones. It consists in clipping off the seed ends or portions of the skin of small tubers intended for planting whole. By this practice, it is claimed, earlier and better germination can be secured than where the surface of the tuber is not mutilated. Where the seed potato is cut, the same result is secured. The actual effect of removal of the skin, or of cutting the tuber, is that of increasing the moisture loss, which seems to result in a greater activity of the life processes of the plant, thereby inducing an earlier germination.

Practices Compared.—While the foregoing methods of handling the seed from the first crop are all bona fide practices, it is but fair to say that all are not of equal importance insofar as their use is concerned. Practice 1 is probably much more generally followed by the growers than all the others combined. It is believed, however, that with a strict observance of the necessary precautions a combination of 2, 3, or 4 with that of 6 would be preferable to that of 1. Number 5 is only feasible where cold storage is available and, as yet, it has not been sufficiently tested to determine its real value. In adopting any of these practices the main object of the grower is to shorten the rest period of the seed potatoes and to secure, as nearly as may be, a hundred per cent germination from those that are planted.

The present practice of planting the culls or unsalable potatoes from the first crop should be discontinued, as it is not possible to secure a maximum yield from potatoes weighing an ounce or less. Much better results would be secured if the grower were careful to select tubers ranging from 1½ to 3 or 4 ounces in weight. Such tubers are sufficiently developed to furnish the necessary vigor to the plants they produce to insure a good crop, provided they have favorable growing conditions.

Quality of Second Crop Seed.—It is not generally known, to northern growers at least, that Oklahoma and Arkansas second crop seed potatoes are considered superior to northern grown seed stock when only once removed from the North. This class of stock is known as "Junior seed;" that is, seed stock purchased, we will say, in Nebraska in the fall of 1919, is planted for an early crop in 1920; the seed obtained from the early crop is planted for a fall or second crop; the seed from this second crop is known as Junior seed. When such seed is grown another year, the second crop seed, say in 1921, is known as Senior seed. Senior seed is generally considered inferior to fresh seed from the North, and it is not extensively used.

Time of Planting Fall and Second Crop.—As the object of growing a fall crop is to produce potatoes for late fall, winter or spring consumption, or for the production of seed for the ensuing year's early crop, the date of planting is largely governed by the date of the first killing frost in the autumn. In other words, planting is delayed as long as it is possible and still be reasonably certain of a sufficiently long growing period to permit the tubers to reach full size, or at least to make a fair crop. Full maturity is not desired in the case of the second crop. A study of the planting dates given in the table shows that they extend from June, in Delaware and Maryland, to October, in Florida.

Yields.—As a rule, the yields from the fall or second crop are not as large as from the early or late crop, except when the season is very favorable to their development, in which case they may greatly exceed the early crop. In the case of the second crop, large yields are not so important as the production of medium sized tubers of high quality for seed purposes.

POTATO PRODUCTION BY STATES

In order to obtain a fairly intimate knowledge of the extent and importance of the potato crop in each of the sixteen southern states, it has seemed desirable to present a brief summary of the industry in each state. It is obvious that in such a discussion it is not possible to enter into very minute details concerning the methods practised in the leading producing centres. Furthermore, cultural practices are discussed in the chapter devoted to that subject.

While first hand information has been obtained, through personal visitation of many of the leading producing centres in the South, claim cannot be made that all points have been visited. It has therefore been necessary to rely upon such information as has been published or secured through correspondents. The data presented are, of necessity, taken from the reports of the Bureau of Crop Estimates.

Potato Production in Florida.—The Florida potato crop is of interest to the student of potato culture, as well as to consumers, from a number of standpoints. In the first place, the crop in some sections, notably in the Hastings district, is grown under some conditions entirely different to those encountered in any other potato-producing section in the United States or elsewhere; and in the second place, it is of interest to the consumer because, outside of foreign sources such as the Bermuda and Isle of Pines crop it is the first large commercial section to supply new potatoes in the spring to northern markets.

Extent of the Crop.—The potato crop of Florida is relatively small as compared with that of the larger potato-producing states of the North, or for that matter with some individual counties as, for example, Aroostook County, Maine. On the other hand, the increase in potato production during the seasons of 1917 and 1918, has been quite marked, as will be noted from a comparison of the yields during the past five years (1915 to 1919):

1915, 12000 acres	960,000 bushels, av. yield per acre 80 bushels
1916, 15000 "	1,110,000 " , " " " " 74 " , increase over 1915-15.6
1917, 25000 "	2,275,000 " , " " " " 91 " , " " " -136.9
1918, 35000 "	3,500,000 " , " " " " 100 " , " " " -264.6
1919, 24000 "	1,824,000 " , " " " " 76 " , " " " -90.0

Localities Where Grown.—The chief potato producing sections in Florida are located in St. John and Putnam counties, commonly spoken of as the Hastings district. The normal potato average of this district is around 11,000 acres, but in 1918 it was variously reported at from 13,000 to 15,000 acres. Kissimmee, in Osceola County, claimed to have 1800 acres in 1918. Lesser acreages were grown in the vicinity of Plant City and Tampa. A considerable potato acreage is grown in the territory surrounding Lake Okechobee, known as the Upper Everglades region, Moore Haven and Okechobee being the largest production centres of this section. A rather small acreage is grown in the vicinity of Miami and a somewhat larger one near Vero. Going north, from this point, a considerable acreage may be found in Volusia County near DeLand. This, in the main, may be said to cover the more important sections of the state.

Varieties Grown in Florida.—Fortunately for the potato industry of the South but few varieties are grown. In Florida, for example, the leading varieties are Spaulding No. 4, or Spaulding's Rose as it is more generally known, and Triumph. The Irish Cobbler is grown, to a slight extent, in Lake Okechobee district. The Triumph is grown in the southern half of the state, and the Spaulding No. 4 in the northern half. The latter variety is grown in the Hastings and Kissimmee areas and, to a slight extent, at Plant City; but elsewhere, with the exception of Volusia County, the Triumph is the leading variety. The reason for this more or less well defined demarcation of areas in which these two varieties are grown is not quite clear, except that each has given best satisfaction in the areas in which they are now grown. There is a possible explanation, however, of the exclusion of Spaulding No. 4 from the southern and western portion of the state; this variety is very sensitive to a check in its growth due to a lack of soil moisture, such a check being almost certain to result in the tubers germinating, and making what is known as "second growth" which invariably gives knobby tubers and a large percentage of culls. The Triumph zone is almost entirely a non-irrigated area.

Potato Production in Georgia.—The Georgia potato crop in 1918 was somewhat less than half that of Florida, the total yield being 1,610,000 bushels, with an average acreage production of 70 bushels.

Production Centres.—The chief commercial production centres are the Savannah and Cairo districts; the former being much more important.

Variety Grown.—The Irish Cobbler is the most extensively grown variety for the early truck crop.

Potato Production in South Carolina.—The 1918 potato crop of South Carolina was more than three times as large as that of the average for the years 1914 to 1916 inclusive, and over twice as great as that of 1917, thus evidencing the response of the growers to their country's call for a larger food production program. The total production of the state, however, even in 1918 is relatively small, (2,856,000 bushels), but as it is practically all harvested as an early crop, it does have an economic bearing on potato prices during the period in which the crop is moved to market.

Production Centres.—The chief production centres are located in Beaufort and Charleston counties and are commonly known as the Beaufort and Charleston districts. The chief shipping points in Beaufort County in order of importance, are Sheldon, Port Royal, and Beaufort. In Charleston County they are John's Island, Charleston, Meggett, and Yonge's Island. The only other point from which any considerable shipment was made in 1916 was that of Myrtle Beach in Horry County.

Potato Production in North Carolina.—The North Carolina potato crop is of considerably greater importance than that of its sister state to the south. Based on its average production for the past five years, (1914-1918), it occupies 28th place among the states of the Union. The 1917 and 1918 crops were approximately 4½ and 4¼ million bushels respectively. The general similarity of conditions, so far as soil, climate, variety grown, and general cultural methods practised is so nearly identical to that of South Carolina as to make repetition unnecessary. There is, however, one feature connected with the North Carolina potato crop that is somewhat different from that of the three states thus far discussed; that is, that a considerable percentage of the crop is grown as a late or main crop, just as in the North. This is due to the mountainous character of the western portion of the State, which affords very similar climatic conditions to those of northern regions.

Production Centres.—The chief early potato producing centres are located around Washington in Beaufort County; Newbern in Craven County; Elizabeth City in Currituck County; Calypso in Duplin County; and Mt. Olivet in Wayne County. Elizabeth City is the outlet or shipping point of peninsula shipments. This point and Mt. Olivet were the heaviest shipping points in the state in 1916.

Potato Production in Virginia.—Within the past two years Virginia has passed from the 11th to the 7th largest potato producing state in the Union. The crop of Virginia is made up, even to a larger extent than is North Carolina, of early and late or main crop production areas. Larger quantities of second crop and fall potatoes are also grown. In fact, the total crop is difficult of analysis as to the relative magnitude of the early or truck crop portion of the crop as compared with the late or main and the second and fall crop. As nearly as it is possible to judge from shipments, the early crop represents approximately 50 per cent of the total. It is hardly necessary to state that the early crop is grown in the coastal plain or eastern section of the state, and that the second and fall crop is also produced in the same area. The late or main crop is grown in the central and western portions of the state where the elevation affords similar climatic conditions to those described in North Carolina.

Potato production in Virginia reached its high-water mark in 1915, when a crop of 17½ million bushels was harvested.

Production Centres.—The two generally recognized potato-producing centres in Virginia are those of the Norfolk and Eastern Shore districts; but as these sections are made up of more than one county, they represent rather large territory, which can perhaps be better considered sectionally or by counties. The Eastern Shore of Virginia consists of two counties, Northampton and Accomac. Cape Charles is the principal shipping centre of Northampton County; but in the case of Accomac, there does not appear to be any particular or outstanding shipping centre. The carload shipments from these two counties in 1916 were 8,386 from Northampton and 6,485 from Accomac. The Eastern Shore district is easily the leading early potato-producing section in the United States so far as volume is concerned.

The Norfolk district includes Norfolk and Princess Anne counties. Most of the potatoes are grown in Norfolk County, of which the city of Norfolk is the leading shipping centre. In 1916, 5,809 cars were shipped from this county as against 221 from Princess Anne County.

Among other Virginia centres that might be mentioned are those of Toano in James City County, from which 343 carloads were shipped in 1916; 1,038 cars from Occohannock River landings and 895 cars from Eastern Shore points, by boat, to Crisfield, Maryland.

In general the soil and climatic conditions of the trucking sections of Virginia are very similar to those in North and South Carolina, the only difference being that the season is just a little later. The soil for the most part is well adapted to potato culture and, when properly drained, responds quickly to good cultural practices.

Potato Production in Maryland.—The early potato crop of Maryland is a relatively small one as compared with Virginia. The bulk of the early crop is grown on the Eastern Shore of Maryland, commonly known as the Maryland peninsula. It is simply a continuation of the Eastern Shore of Virginia district.

The total crop of the state for the past five years including early, late, second and fall crops, averages less than four and one-half million bushels. In 1917 the production was six million bushels, in 1918 about four and one-quarter million, and in 1919 almost five and one-sixth million bushels.

Production Centres.—Worcester County, adjoining Accomac County in Virginia, is the chief production centre with a total of 1197 carloads. Baltimore is credited with 2170 cars, but it is quite evident that a considerable percentage of these shipments must have represented trans-shipments of potatoes arriving in Baltimore by boat, and not, as might be inferred, actual production in the vicinity of the city.

Potato Production in Delaware.—The potato crop of Delaware is of such small magnitude, as far as its influence on the total production of the country is concerned, as to be almost negligible. In point of production, Delaware ranks as 45th state. The average for the years 1915 to 1919 is only a trifle over one million bushels. The total shipments in 1916 were only 121 cars, of which Sussex County contributed 101 cars. Nassau, Selbyville, Frankford and Georgetown in Sussex County, and Wyoming in Kent County were the heaviest shipping points.

According to the Bureau of Crop Estimates, 5 per cent of the crop was harvested in June, 23 in July, 24 in August, 13 in September, 19 in October, and 16 in November.

It is quite evident, from the above data, that fully 50 per cent of the crop grown could be classed as late or main crop potatoes. The Irish Cobbler is the favorite early variety, and a red skinned potato of the Rose group as a late variety.

Potato Production in Alabama.—In point of production during the last five year period (1915-1919) the state of Alabama ranks 33rd. The average production during this period was nearly 3 million bushels. The 1918 crop was 63 per cent larger than the five year average or 4.8 million bushels. The 1919 crop shows a decrease of nearly 27 per cent from that of the 1918 crop, due wholly to a curtailment of acreage as a result of unsatisfactory prices in 1918.

Production Centres.—The chief potato production centres are located in Mobile and Baldwin counties in the southern part of the state. Mobile, Theodore, and Dawes are the chief shipping points in Mobile County, and Foley in Baldwin County. The area planted to early potatoes, in 1916, in these two counties was estimated at about 2000 acres. No large growers were noted in Mobile County in 1916. The maximum acreage observed on any farm did not exceed ten acres.

Potato Production in Mississippi.—The potato crop of Mississippi, like that of Alabama, is a comparatively unimportant one. The average production of the state for the past five years, 1914 to 1918, is a trifle over 1.1 million bushels. It ranks as 44th state in volume of bushels produced.

Production Centres.—Comparatively speaking one can hardly claim any real centres of early crop production, as the quantity shipped is almost too small to be taken into consideration. Adams and George counties are the heaviest producing sections; the first representing a shipment in 1916 of 35 cars, and the latter 34. Natchez is the leading shipping point in Adams County and Evanston in George County.

Potato Production in Louisiana.—One of the most interesting features of potato production in Louisiana is the fact that the growers have not, as in most of the other southern states, centred on a single commercial variety. While the Triumph is the leading variety, it has a strong competitor in a variety locally known as "Long White" which the writer believes to be a member of the Burbank group—probably White Star. Another point of interest is the remarkable response of the growers, in 1918, to the appeal for a larger production of food crops; and doubtless, too, as a psychological effect of the high prices received for the 1917 crop. The acreage in 1918 was over 111 per cent greater than the average of the three preceding years and, in point of production, the crop was almost three times as large or 4,345,000 as compared to the three year average of 1,551,000 bushels. The average per acre production of the state for the years 1915 to 1919 was 67.1 bushels. The 1919 production was 1,600,000 bushels, or a trifle over 2.3 per cent greater than the previous four year average.

Production Centres.—In by-gone days the Alexandria and Shreveport districts were generally recognized as the leading potato growing sections; but in 1916, a personal visit revealed the fact that the Shreveport district had long ceased to produce potatoes on a commercial scale; and that the Alexandria district was not as important as had been supposed, less than 2,500 acres being devoted to the crop in that season. Some rather remarkable changes in acreage have taken place since 1917, as is evidenced from the following data on the 1918 crop, secured from the Bureau of Markets.

Avoyelles, Parish or County......	1,800 acres,	Triumphs
East Baton Rouge, Parish or County	1,900 acres,	Triumphs
East Feliciana, Parish or County..	1,500 acres,	Triumphs
Iberia, Parish or County	2,300 acres,	Triumphs
Iberville, Parish or County	1,200 acres,	Triumphs
LaFourche, Parish or County......	17,500 acres,	Long Whites (Burbanks probably)
Plaquemines, Parish or County	1,700 acres,	Long Whites and Triumphs
Point Coupee, Parish or County ..	2,650 acres,	mostly Triumphs
St. John Baptist, Parish or County	2,000 acres,	Triumphs and Long Whites
St. Landry, Parish or County	1,200 acres,	Triumphs and Long Whites
St. Mary, Parish or County	1,700 acres,	mostly Triumphs
Terrebonne, Parish or County	1,600 acres,	Triumphs and Long Whites
West Feliciana, Parish or County..	1,850 acres,	mostly Triumphs
Total of 14 counties..........	38,900 acres	
Remaining 22 counties	6,960 acres	
Total	45,860 acres	

It is interesting to note the very large acreage in LaFourche County, amounting as it does to almost half of the total acreage of the 14 counties, and considerably over a third of the acreage of the whole state as here given. It is, however, less than one-third of the acreage reported by the Bureau of Crop Estimates, which is 9,140 acres greater than the above data. Such a discrepancy can be readily accounted for, as the Bureau of Markets data probably only took into consideration the early crop, while the Crop Estimates report included both the early and the fall crop.

The fact that two varieties are grown commercially is also of interest as, outside of Florida, it is the exception rather than the rule. It is especially interesting to note that the Long White (White Star) variety is largely, if not almost exclusively grown, in the southeastern part of the state, or the region which might be regarded as tributary to New Orleans. It simply illustrates the fact that the Long White variety is either better adapted to the soil and climatic conditions of this region, or that the growers are catering to a distinct preference on the part of the trade, for white skinned varieties.

Potato Production in Texas.—Texas ranks as 34th state in point of production. The average bushels produced during the five years, 1915 to 1919, is 2,917,200 with a maximum production in 1919 of 3,796,000. A comparison of the acreage production of Texan potato fields with those of other southern states, shows that the yield, 60.8 bushels, is less than that of any of them. The reason for such low yields is that the crop is a rather uncertain one, owing to its being subjected to such variable and trying climatic conditions.

Viewed in its entirety, the potato crop of Texas is comparatively insignificant when the size of the state is taken into consideration; yet there are a few localities in which the crop is a fairly important one.

Production Centres.—The chief commercial potato centres in Texas are the Wharton and Eagle Lake districts, located in Colorado and Wharton Counties respectively; Simonton and Fulshear in Fort Bend County; and Brownsville and San Benito in Cameron County. The car lot shipments in 1916 from Eagle Lake were 441; Wharton 343; Egypt and Glen Flora in the same county 103 and 58; Simonton 193; Fulshear 41; Brownsville 101 and San Benito 50. The total shipments reported by the Bureau of Markets in 1916, 1917 and 1918 were 1,649, 1,671, and 2,312 cars respectively.

Potato Production in Oklahoma.—The average production of potatoes in the state of Oklahoma during the years 1915 to 1919 was less than 2½ million bushels or to be specific 2,496,200 bushels. The average yield per acre was 62.7 bushels or the second lowest in the Union. If judged by car lot shipments, the potato crop of Oklahoma would not take very high rank as a commercial industry. The shipments for 1916, 1917 and 1918 were 1,424, 625, and 349 respectively. These figures are not substantiated by those of the Bureau of Crop Estimates, which show more than a 33⅓ per cent increase in the 1917 crop over that of 1916; despite this fact the shipments were over 50 per cent less. It is presumable that the 1917 and 1918 Bureau of Markets data, issued under date of January 28, 1919, does not represent as complete a record of the car lot movements as in 1916. The crop movement is between May 25 and July 15.

Production Centres.—The heaviest production centres are located in Muskogee, La Flore and Sequoyah. Fort Gibson, Webbers Falls, Wybark and Muskogee are the heaviest shipping points in Muskogee County; Spiro in La Flore; and Gore, Vian and Muldrow in Sequoyah County. The total car lot shipments from each of these counties is as follows: Muskogee 7,811, La Flore 2,671, and Sequoyah 192. Of the 781 cars shipped from Muskogee County, 461 are credited to Fort Gibson, which is the centre of the commercial potato area and is located in the Arkansas River Valley. A considerable proportion of the crop in this section is grown on the fertile river bottom lands, which for the most part consist of a light sandy loam well adapted to potato culture.

It is interesting to note that in 1891 the horticulturist of the State Experiment Station, O. M. Morris [3] stated that the largest commercial potato growing district in Oklahoma at that time was confined to the valley of the North Canadian river in Pottawatomie County. The 1916 shipments from this county were 62 cars, 57 of which were from Shawnee and five from Dale. This affords an excellent illustration of how production centres may shift from year to year, or from decade to decade. The shifting of truck crop centres is, perhaps, more largely confined to the South than to the North; and this is particularly true with respect to the potato crop which, outside of a few well recognized districts, is more or less of a catch crop with the trucker, and is subject to wide fluctuations in acreage, according to whether prices rule high or low.

Potato Production in Arkansas.—As a potato growing state Arkansas stands as 35th state in point of production. The average for the past five years, 1915 to 1919, is nearly two and three-quarter million bushels, (2,709,000), and the average yield per acre for the same period is 72.1 bushels. The total car lot shipments reported for the state in 1916 were only 537. It is evident therefore that, from a commercial standpoint at least, it exerts little influence on the outside markets.

Production Centres.—Commercially speaking there is but one production centre worthy of consideration. This is the district surrounding Fort Smith in Sebastian County, from which 383 of the 537 cars were shipped. Of this number 313 were moved from Fort Smith. Other points that might be mentioned are Alma, in Crawford County, 30 cars; Booneville, in Logan County, 25 cars; Charleston, in Franklin County, 23 cars; and Rob Roy, in Jefferson County, 18 cars. It is quite apparent from these figures that the real commercial area of potato production is in the vicinity of Fort Smith. The Fort Smith figures may, however, be misleading; it is altogether probable that they include a considerable portion of Oklahoma-grown potatoes, as the river bottom lands on both sides of the Arkansas river are largely planted to potatoes in this particular locality.

In some respects the soil and the general lay of the land, both in Arkansas and Oklahoma in the Fort Smith district, is ideal for potato culture. The sandy loam soil is of alluvial origin, and is easily kept in good physical condition provided any reasonable attention is given to the maintenance of a good supply of organic matter. The Triumph is the leading early variety.

Potato Production in Tennessee.—Based on its five-year average, Tennessee stands 6th in point of production of the sixteen states, regionally grouped as southern states by the Bureau of Crop Estimates. It ranks 28th among the 48 states of the Union, with a total average production during the years 1915 to 1919 of 3,525,600 bushels, and an average yield per acre of 79.4 bushels. As 57 per cent of the crop is harvested after September 1, it is safe to assume that the potato is quite largely grown as a late or main crop, or a fall crop rather than as an early or truck crop.

Production Centres.—The heaviest shipping section is found in Gibson County, from which some 576 carloads were moved in 1916. Lauderdale County is next with 133 cars. The leading shipping stations in Gibson County are Gibson 198, Milan 156, Humboldt 130, Fruitland 60, Medina 20 and Bradford 12. Halls is the leading shipping point in Lauderdale County. The Cumberland Plateau in Cumberland County offers possibilities for the development of a considerable industry in the production of late or main crop potatoes. Second crop potatoes are also grown quite extensively in some parts of the state. Columbia is the centre of the second crop potato industry.

Potato Production in Kentucky.—The potato crop in Kentucky ranks 21st in point of production with an average of over

5½ million bushels. The response of the Kentucky farmer to the appeal for a larger crop of potatoes, as well as other food crops, is well shown by the increased acreage in 1918. A comparison of the 1918 acreage with that of 1915 shows a 47 per cent increase in favor of 1918. If the necessary data were available it could probably be shown that the potato crop of Kentucky, like that of Tennessee, is very largely made up of late, second and fall crop varieties.

Production Centres.—Jefferson County, Kentucky, is by all odds the leading potato-producing centre, as it includes the well-known Louisville district. The total car lot movements reported for the state by Froelich,[2] for 1916, was 1,399, and of this number Jefferson County is credited with 1356. Louisville and St. Matthews are the two leading shipping centres with 556 and 326 car lots respectively; Lyndon shipped 163; O'Bannon 117; Buechel 115; Prospect 34; Jeffersontown 23; Anchorage 20; and Lakeland 2.

Potato Production in West Virginia.—While the state of West Virginia is geographically included in the southern group of states, it naturally belongs to the northern or late crop group. The Monthly Crop Report of the Bureau of Crop Estimates for November, 1916, p. 116, gives the percentage of the crop harvested per month as 1 per cent in June; 7 in July; 16 in August; 36 in September; 37 in October, and 4 in November. It is thus seen that less than 25 per cent of the acreage planted is harvested as an early crop. The average yield during the years 1915 to 1919 was over 5¼ million bushels, and the yield per acre 99.3 bushels. In relative importance West Virginia ranks 22nd.

In discussing the comparative importance of the potato crop, Dacy[1] says:

"It will be noted that the area devoted to the potato crop (in 1909) averages less than half an acre to the farm......The only counties which ship their product outside of the state to any extent are those lying along the Ohio River. Their surplus goes to the markets of Pittsburgh, Pennsylvania; and to Cincinnati and Columbus, Ohio. Even if every bushel produced was kept at home, we would still have to import from other states enough to feed our own people......There seems to be no valid reason why West Virginia should depend upon the farmers of other states to furnish such a large share of the potatoes consumed by her people, when there are thousands of acres of land within her borders that are splendidly adapted to the growth of this crop."

The physical aspects of the state are such that one can easily find climatic and soil conditions admirably suited to the growing of either an early or a late crop; the range in altitude varies from 260 to 4,860 feet, thus affording at the higher altitude, say 1,800 to 3,000 ft., climatic conditions admirably adapted to the production of a late crop, which could be marketed for table or seed stock, according to where it was produced and the variety grown.

Production Centres.—Strictly speaking, there are no well defined potato production centres in the state, unless one might choose to consider those counties bordering the Ohio River, some of which grow a good many Early Ohio for the Pittsburgh, Cincinnati and Columbus markets. These are dug early and, as a rule, are at once shipped to market. The Bureau of Markets reports that only 59 cars of the 1916 crop were shipped from points of production.

QUESTIONS ON THE TEXT

1. What are the chief points of difference between potato production in the South and in the North?
2. How many crop periods are there in the South? What are they called?
3. Into how many geographical sections has the Bureau of Crop Estimates divided the United States? Name them.
4. Name the southern States.
5. What proportion of the 1920 potato crop did the South produce?
6. Why does the southern potato crop command a better a price, as a rule, than the northern?
7. What is the relative importance of the early crop to that of the late and fall crops?
8. In which portion of the South is the percentage of early to late or fall crops greatest? Mention some of the States.
9. Is potato production in the South capable of much expansion? Give reasons.
10. What are the chief advantages to the grower of being located in a production centre?
11. Why is the southern grower more dependent upon active selling than the northern grower?
12. What are some of the conditions that are generally regarded as being favorable to the production of an early crop of potatoes?
13. Name some of the leading commercial centres of potato production.
14. Why are sandy loam soils preferred for early crops?
15. What are the varieties chiefly grown for the early crop?
16. From what localities does the southern grower obtain his seed? At what time of year?
17. Throughout what months is the early crop planted?
18. What is one of the chief risks encountered in growing an early crop?
19. In what particular portions of the South are late or main crop potatoes grown?
20. What are the chief points of difference between the fall crop and the late crop?
21. Of what does the fall crop proper consist?
22. What is meant by second crop potatoes?
23. In what portions of the South are fall crop potatoes usually grown?
24. What varieties are grown for fall crop production?

25. What is the origin of the White McCormick? Is it as good as the McCormick?
26. What are the sources of seed supply for the fall crop?
27. What classes of varieties are included in second crop production?
28. Within the strict meaning of the term "*second crop potatoes*" what should it include?
29. What is the source of seed supply where the Irish Cobblers are grown?
30. Describe practice No. 1. Why is it so important?
31. Describe practice No. 2 and compare with No. 1.
32. Describe practices Nos. 3 and 4.
33. Describe practice No. 5.
34. Describe practice No. 6 and give its relation to the others.
35. Is the present practice of using the culls a desirable one? Give reasons.
36. What should be the determining factor as regards the date of planting fall or second crop potatoes?
37. Why is it desirable to delay planting as long as possible?
38. Is full maturity desired in the second crop? Give reasons.
39. How does the yield from fall or second crop potatoes compare with that of the early crop?
40. Of what particular interest is the Florida potato crop to the student of potato culture and the consumer?
41. What varieties are grown? Give portions of Florida in which grown.
42. What variety does the Georgia trucker grow?
43. How does the 1918 crop in South Carolina compare with that of 1914 to 1917?
44. How does the North Carolina potato crop compare with that of South Carolina?
45. In what respect does North Carolina's potato crop differ from that of the three preceding states?
46. What position does Virginia hold as a potato producing state?
47. In what parts of the state are the crops produced?
48. Of what importance is the early potato crop in Maryland as compared with that of Virginia?
49. Is the potato crop of Delaware of much relative importance? What position does it occupy?
50. What was the average production of Alabama for the years 1915 to 1919 inclusive?
51. What is the rank of Mississippi as a potato producing state?
52. What is one of the interesting features about potato production in Louisiana?
53. What varieties are grown?
54. What is the average per acre production for the state as a whole?
55. Name the chief production centres. Which is the most important?
56. Where is the Long White (White Star) variety most largely grown?
57. What was the average potato production of Texas during the years 1915-1919 inclusive?
58. What record does she hold in production per acre?
59. What reasons are assigned for the low yield?
60. What are the chief commercial centres?
61. What was the average production in Oklahoma for 1915 to 1919 inclusive?
62. What rank does she hold in production per acre?
63. During what period is the crop moved to market?
64. What is the rank of Arkansas in point of production?
65. What is the leading variety?

66. What is the rank of Tennessee in point of production both in the South and in the United States?
67. What percentage of the crop is harvested after September?
68. Of what importance is the Kentucky potato crop?
69. What are the leading production centres?
70. Of what importance from an early crop standpoint is the West Virginia potato industry?
71. What does Dacy say about the potato crop of the state?
72. What are the leading production centres?

QUESTIONS SUGGESTED BY THE TEXT

1. How many crop periods in your region? What are the dates of planting?
2. To what geographical section does your region belong?
3. What other states are in it?
4. What varieties are most grown in your region?
5. What are the most noted production centres in your state?
6. How do these compare with other centres in the United States?

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CHAPTER X

POTATO PRODUCTION IN THE NORTH AND WEST

In the preceding chapter, the early or truck crop potato-producing sections in the South were considered both with respect to the extent of the crop grown as compared with the total crop of the United States as well as to the relative importance of the crop in each state. It was shown that the 16 states geographically considered as belonging to the South only produced a little over 15 per cent of the total crop. When it is remembered that this percentage includes all the early, late and fall crop of potatoes grown in the South, the significance of the comparison and the relative importance of potato production in the North and West becomes at once apparent.

The Potato Essentially a Northern Crop.—While the production of late or main-crop potatoes is not entirely confined to the North, it is in a commercial sense very largely restricted to the northern tier of states. This is by no means due to an accidental circumstance, but rather to a direct recognition of the fact that the potato is essentially a cool-loving plant; it therefore thrives best where the summer temperatures are relatively low and where the rainfall is sufficient to keep the plants in an active stage of growth throughout the season. Such climatic conditions are quite generally found in the northern part of the United States and Canada, and in some of the more elevated portions of the South and West.

Altitude, as well as latitude, is an important climatic determining influence so far as temperature is concerned, and must be reckoned with in the consideration of the suitability of a given region to any particular crop.

Confirmation of these statements, insofar as their application to the late potato crop is concerned, is not lacking as one has only to call attention to the leading potato-producing states, such as New York, Minnesota, Wisconsin, Michigan, Maine and Pennsylvania to partially, at least, prove the truth of this assertion. The average production of these 6 states, during the years 1915 to 1919, was over 43.1 per cent of the total crop of the United States.

Market is Another Factor.—It would be misleading, as well as unjust, however, to other equally as well favored states, climatically at least, to assume that this large production was wholly due to exceptionally favorable soil and climatic conditions. There is another factor which determines to a very large extent—in fact, it may be considered the sole limiting factor in many sections of the United States; this factor is that of proximity to market or to the large consuming centres. The potato is a bulky, and relatively cheap selling food product, and on that account there is not a sufficient margin between the cost of production and the selling price of the crop to permit of the absorption of a very heavy transportation charge. This limiting factor is, therefore, responsible for the relatively light production of the eleven far-western states. The production of these eleven states for the years 1915 to 1919 has averaged just a trifle under 14 per cent of the total crop of the United States. If one attempted to judge the adaptability or suitability of the various states, in this country or in foreign ones, for the production of potatoes solely by the extent of the crop produced, they would very likely form an erroneous opinion or arrive at an entirely wrong conclusion regarding the real causes of heavy or light production.

Two Important Factors.—If an intelligent understanding of the subject is to be reached, one must consider the following two factors: (a) average production per acre, and (b) the production cost per bushel. These two factors are, of course, largely determined by the progressiveness of the growers as regards their cultural practices and the care they exercise in the production and use of good seed stock. A comparison of the average acre production of the six largest northern potato-producing states with that of the eleven far-western states for the five-year period, 1915 to 1919, shows that the former produced only 90.3 bushels per acre, while the latter averaged 133.3 bushels or an increase of 43 bushels. It is evident, therefore, that the six heavy producing northern states do not enjoy any special advantage as regards climate or soil. The real explanation of their large production is that of proximity to large consuming centres.

Late or Main Crop Production Centres.—Potato production in the North and West is not so generally confined to distinctive production centres as in the South. There are, however, certain well known sections which are generally recognized the country over as important potato-producing areas. These sections are

Aroostook County, Maine; Long Island and western New York; Monmouth County, New Jersey; Waupaca and Stevens Point, Wisconsin; the Red River Valley in Minnesota and North Dakota; the Kaw (Kansas River) Valley in Kansas; Greeley, San Luis Valley, Carbondale and Montrose districts in Colorado; the Idaho Falls and Caldwell districts in Idaho; the Yakima Valley in Washington; and the Stockton district in California. While the above localities are the more widely known potato production centres, they do not necessarily represent all of the important sections. In fact, outside of Aroostook County, Maine, western New York, and Greeley, Colorado, there are a number of other districts such as southern New Jersey, northeastern Ohio; the central and northern portion of the lower peninsula of Michigan, and many others in which potatoes are produced on a much larger scale than in some of the better known areas mentioned.

Aroostook County, Maine.—The state of Maine has long enjoyed the distinction of having within its borders a county that produces on the average more potatoes annually than all but the six leading states, of which Maine herself is the fifth in point of production. It is probably not so well known that the area of Aroostook County is almost equal to that of the whole state of Massachusetts and that, notwithstanding its large average annual production of potatoes, 17½ million bushels, less than one-fourth of the land in the county has been brought under cultivation. One may well inquire into the reason for this seemingly large development of commercial potato production in this somewhat remote market region of the United States. The most logical reasons which present themselves are that the soil and climatic conditions are extremely favorable to the potato crop; the climate is too cool for the successful production of corn or other cultivated cash crops, hence the farmers have come to regard the potato as their chief agricultural money crop; and to look upon grain and hay as merely necessary evils in the practice of a safe and economic crop rotation system.

Soils.—The soils of Aroostook County are of glacial origin, but are not thought to have been transplanted very far. They are mostly derived from the shaly Aroostook limestone, which underlies a large portion of this area. Westover and Rowe[7] classified the soils derived from the unmodified glacial drift into eight distinct types, the most important of which is the caribou loam. This type of soil is especially suited to the production of potatoes.

Climatic Conditions.—The climatic conditions that prevail in Aroostook County vary considerably from those which obtain in the southern part of the state. The temperature is much lower in the winter and does not rise as high in the summer; the rainfall, while not always as copious in the growing season, is usually more evenly distributed; and it is seldom that the potato crop of Aroostook suffers very seriously from either heat or drought. These two

Fig. 58.—A field of Irish Cobblers just coming into bloom. Aroostook Co., Me.

factors—heat and drought—exert a much more marked influence on tuber production than we are wont to consider.

Varieties Grown.—The leading commercial varieties grown in Maine are the Irish Cobbler and the Green Mountain. In the case of the latter variety, it is supposed to include the members of the group, such as the Gold Coin, Snow, Norcross, etc. The Irish Cobbler is grown both for seed and table purposes, while the Green Mountain is grown almost exclusively for table use. In addition to these, the following varieties are grown for seed purposes as, for example, the Spaulding No. 4, American Giant, Triumph, Early Ohio, Early Rose, and Quick Lunch. The last three varieties are sparingly grown by a few seed growers.

Potato Blossoming.—In no other section of the United States yet visited by the writer does the potato plant bloom as freely as in northern Maine. The reason for this is that the plants rarely suffer a check in their growth due to heat or drought during the period in which the blossoms are developing. As a result of these favorable conditions, many potato fields in northern Maine have the appearance of an immense flower garden (Figs.

Fig. 59.—A field of Irish Cobblers in full bloom. Aroostook Co., Me.

58 and 59). The Irish Cobbler and the Green Mountain varieties are especially free bloomers.

On account of the favorable climatic and soil conditions in Aroostook County, Maine, the United States Department of Agriculture has conducted some rather extensive potato experiments in this section since 1911. At present, practically all of the breeding, selection, seed development and varietal testing are located on Aroostook Farm, Presque Isle, Me. (Fig. 60.) (Aroostook Farm is a State Experimental Farm operated by the Maine State Experiment Station).

Production Centres in Aroostook County.—While the county is usually regarded as the unit in the discussion of state production, it is believed that owing to its size, a somewhat more special or minute consideration may be given to certain portions of it. The northern half of the Aroostook Valley is generally conceded to be superior to the southern half for the growing of potatoes. The heaviest producing section is that portion included between Mars Hill, and Limestone, embracing the towns of Mars Hill, Easton,

Fig. 60.—Dwelling house and barn on "Aroostook Farm," Presque Isle, Me. Aroostook Farm is a State Experiment Farm operated by the Maine State Experiment Station, Orono, Me. The U.S. Department of Agriculture carries on its potato breeding work on this farm.

Fort Fairfield, Presque Isle, Caribou and Limestone. In 1913, the Bangor and Aroostook Railroad prepared a sketch map showing the distribution of potato shipments over their line (Fig. 61). The map also gives the number of miles tributary to each point, the car movement per mile and the percentage of the crop it represents. For convenience of reference the data are considered under ten zone numbers. The heaviest movement per mile of road operated was that of zone 6 or the Fort Fairfield Branch on which 260 cars per mile were moved. The next highest is that of the Limestone Branch, zone 5, with 187 cars per mile, and zone 2, third, with 180 cars per mile.

The Long Island, New York and New Jersey Districts.—While these two districts are not exactly identical as regards climate and soil, the variations are no greater than those found within Aroostook County. The planting and harvesting seasons are

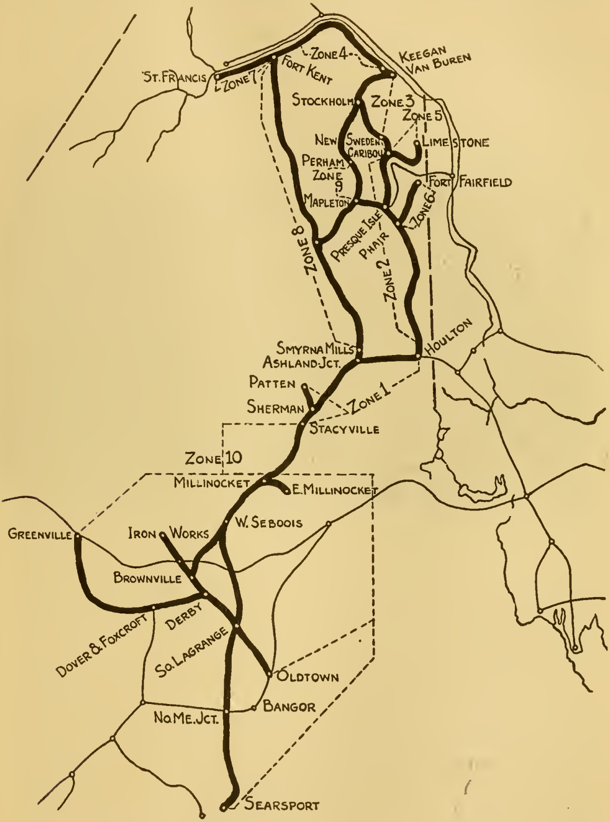

FIG. 61.—Sketch map Bangor and Aroostook R.R. showing distribution of potato shipments. Houlton, Me., April 20, 1917.

also practically identical, thus making it possible to consider them as one district. The points of differences between the combined sections and that of Maine are that the Long Island and New Jersey areas have two distinctive planting seasons, *viz,* an early and a late. The Irish Cobbler is almost wholly grown for the early crop and the Green Mountain as a late, with the exception of Monmouth County, New Jersey, where it is supplanted by the American Giant, which is an intermediate variety, planted about

Fig. 62.—Harvesting potatoes on a Minch Bros. farm, Bridgeton, N. J. Potatoes are gathered in ⅝ bushel baskets. Courtesy of Minch Bros., Bridgeton, N.J.

the same time as the early crop. In addition to these three, a red skinned variety belonging to the Rose Group, which we have been unable to identify, is grown to some extent as a late crop, for which purpose it seems to be admirably adapted.

Production Centres.—The chief potato-producing centres in New Jersey are located in Monmouth, Salem, Mercer, Middlesex and Cumberland Counties. The chief shipping points are Freehold, Howell, Marlboro, Tennent and Englishtown in Monmouth; Salem, Woodstown, Elmer and Daretown in Salem; Hightstown, Robbinsville, Yardville and Windsor in Mercer; Cranbury and Prospect Plains in Middlesex; and Bridgeton and Husted in Cumberland County.

The Long Island district is represented by Suffolk County, in which the leading shipping points are Riverhead, Aquebogue, Cutchogue, Bridgehampton, Southold, Mattituck and Orient.

Soil and Climatic Conditions.—The soil in the more intensive potato-producing areas on Long Island and in New Jersey is of a more or less sandy nature, and could be designated as belonging to the Norfolk series, being a continuation of the same general type of soil as that of the Eastern Shore of Maryland and Virginia.

The climate of Long Island is very much modified by the ocean

Fig. 63.—Specially constructed wagon body racks permit of hauling a large number of baskets. Courtesy of Minch Bros., Bridgeton, N. J.

on the south and east and the Sound on the north; this imparts to the surrounding territory a milder and more equable climate than that which prevails in the same latitude further inland. The climate of New Jersey, especially that of the southern half of the state, is not as well suited to the potato as is that of Long Island, because it is generally warmer and drier. In New Jersey, the practice of planting second crop home grown seed is on the increase, but the bulk of the seed is procured in the North.

Source of Seed.—The Long Island grower is almost wholly dependent upon northern grown seed. Maine, Vermont and northern New York growers supply the bulk of the seed used. Some New Jersey second crop seed is planted, but, as yet, the amount used is rather negligible.

During the past year, (1920), Wisconsin Green Mountains, and Prince Edward Island American Giants have been planted to some extent.

Cultural Practices.—In general, the same cultural methods are pursued as in Maine, with this exception, that both the level and modified ridge culture is practised. The distance and rate of planting is very much the same, as is also the use of commercial fertilizers, with the possible exception that they are not used quite as prodigally as in Maine. As a rule, the fertilizer applied to the early crop contains a higher percentage of available nitrogen than is used by the Maine grower, this being done for the purpose of hastening the development of the plants. Few growers in either of these sections practise spraying as thoroughly as in Aroostook County. This is partly due to the absence of late blight in so many of the seasons that the grower becomes careless and is willing to take a chance, with the result that every few years his crop is severely attacked with the disease, and heavy losses through tuber decay are incurred. This was the case in some counties of New Jersey in 1919, when a severe attack of late blight caused considerable loss.

Harvesting the Crop.—The southern half of New Jersey harvests its potato crop somewhat in advance of the northern half of the state, as well as of Long Island. The crop movement from New Jersey in 1916, as indicated by percentage of crop harvested, shows that 2 per cent was dug in June, 18 in July, 36 in August, 26 in September, and 18 in October.[1] This data affords a fair index to the proportion of the crop that is grown for early and late marketing; it is not necessarily an accurate one because, in either of the two districts under consideration, the harvesting of the early crop is materially hastened or delayed, according to whether prices are high or low during the normal period in which it should be dug. A considerable portion of the New Jersey crop is handled in five-eighth bushel baskets (Figs. 62 and 63).

New England and Northern New York.—The New England States, exclusive of Maine, and northern New York are sufficiently identical in climatic conditions, cultural practices, and varieties grown to be considered as one general area. With few exceptions, potatoes are not grown in this region as an early crop. Outside of northern New York and certain towns in Vermont, very little seed stock is grown other than for local use. The Irish Cobbler is the leading early variety, and the Green Mountain the leading late one. The crop is usually planted during May and the first week in June; though in the more favored sections of Connecticut, Rhode Island, and Massachusetts, the crop is often planted in April, especially early varieties such as the Irish Cobbler, Quick Lunch, and others. Few large growers are found in this area, the average acreage of commercial growers ranging from 2 to 20 acres, with an occasional grower considerably exceeding this amount.

Western New York and Pennsylvania.—The general potato-producing sections of western New York and Pennsylvania are very much alike, insofar as varieties grown are concerned. Most of the potato crop produced in this region, outside of areas adjacent to the larger cities, consists of late varieties intended for fall and winter consumption. A comparison of the production of these two states during the years 1910–1919, inclusive, shows a variation in New York State from a trifle over 22 million bushels in 1915 to nearly 53.25 million bushels in 1914, with a variation in acreage of only a trifle over 3 per cent. The range of variation in Pennsylvania was from a little over 15 million bushels in 1911 to 29.5 million in 1917, with an acre increase in favor of the latter period of about 16 per cent. The varieties most commonly grown are chiefly members of the Green Mountain and Rural groups. The Rural varieties are more generally grown as they have proven to be better adapted to the climatic conditions of western New York and certain sections of Pennsylvania than the Green Mountain class. In Washington County, New York, the American Giant is rather extensively grown for the New Jersey seed trade. The Irish Cobbler and the Early Ohio are the leading early varieties.

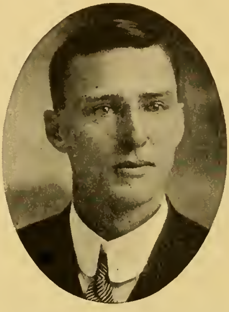

FIG. 64.—Daniel Dean, Nichols, N.Y. A noted authority on potato culture who has been highly successful in the production of large crops of high quality potatoes. Mr. Dean makes a speciality of the Rural New Yorker variety. He is also well known as a writer and platform speaker. His practical experience coupled with keen powers of observation and an ability to impart his knowledge thus gained make him a forceful writer and lecturer.

Cultural Practices.—Cultural practices vary in different localities. In some sections the planting of the late crop is delayed until the latter part of May or forepart of June; this is particularly true in western New York, while in other sections, the crop is planted the latter part of April or early in May. The date of planting is governed, to a large extent, by the normal weather conditions prevailing in any given locality at the time the plants are developing their tubers. Roberts and Clinton [5] say: "Early planting of potatoes and frequent tillage to conserve moisture will ordinarily give best results."

The New York growers, as a rule, plant larger acreages than do New England or Pennsylvania growers. Modern potato implements are very generally employed in the planting, care, and harvesting of the crop. The ridge or hilling system of culture is quite generally practised throughout New York State. There are those, of course, who prefer level culture but they are in the minority. In Pennsylvania, both systems are in vogue. Investigations reported by Stone,[6] in 1905, would seem to indicate that level culture, at least in the vicinity of Ithaca, was preferable to hilling. The following data covering three seasons are taken from Stone's report:

1897—	hilled,	yielded at the rate of 288 bushels per acre,
	level,	yielded at the rate of 384 bushels per acre, 96 bu. increase.
1898—	hilled,	yielded at the rate of 327 bushels per acre,
	level,	yielded at the rate of 345 bushels per acre, 18 bu. increase.
1899—	hilled,	yielded at the rate of 194 bushels per acre,
	level,	yielded at the rate of 241 bushels per acre, 47 bu. increase.

Spraying is no more general or thorough in these two states than in New England. There are, however, some very worthy exceptions. Two of the most striking that have attracted my attention are those of Daniel Dean of Nichols, N. Y., (Fig. 64) and T. E. Martin of West Rush, N. Y. These gentlemen are firm believers in thorough spraying. They are not satisfied to call their job done when they have sprayed their potato fields, four, six, or even eight times, but have been known to spray as often as sixteen times during the season. The increased yields they secure are, in their judgment, ample justification for the extra spray material and the labor involved in making so many applications. In all of the strictly commercial sections the crop is harvested with the elevator type of potato digger. Most of the New York State growers use bushel crates in which to pick up and haul the potatoes to the storage house or cellar (Fig. 65). As a rule, neither New York

Fig. 65.—Harvesting Sir Walter Raleigh potatoes, T. E. Martin's farm West Rush, N.Y. The potatoes are picked up in bushel crates. Courtesy of T. E. Martin.

or Pennsylvania growers have made as ample provision for the storage of the potato crop as have either the Maine growers or those in the "far-west" states such as, Colorado, Utah, and Idaho. The house or barn cellar rather than the special potato storage house is utilized quite generally throughout both states under consideration.

The per acre yield in both New York and Pennsylvania is far below what it should be, and what it must be in the near future, when greater demands will be made upon all tillable lands to produce larger supplies of food. The average per acre production of New York for the years 1915 to 1919 is only 87.1 bushels; and that for Pennsylvania is still less, 82.8 bushels. When it is remembered that Long Island and northern New York, where larger yields are secured, are included in this average, it is evident that the average yield in western New York is considerably less than the figure mentioned. That yields very largely in excess of these may be grown, when proper cultural care is given to the crop, have been amply proven by Roberts and Clinton,[5] in their four reports on potato culture. From these four publications the following data on yields secured on the Station farm are presented:

1895—352.6 bushels
1896—333.0 bushels
1897—322 0 bushels
1898—278.0 bushels
1899—202.0 bushels
1900—200 0 bushels

These data are significant in that they furnish conclusive evidence of the feasibility of very materially increasing the per acre yield of potatoes, not only in New York State, but in every other state where climate and soil are favorable to the growth of the potato plant.

Ohio, Indiana, Illinois, Iowa, and Missouri.—These five states represent the central portion of the geographical area included in the Bureau of Crop Estimates division known as the North and

Average Acreage Production and Yield Per Acre and Principal Varieties Grown—1915-1919.

State	Rank in production	Acreage	Yield in bushels	Bushels per acre	Principal varieties grown
Ohio....	8	152,600	12,027,200	78.2	Early Ohio, Green Mountain, Rural
Illinois..	10	137,000	10,715,800	78.0	Early Ohio, Early Michigan, Rural
Iowa....	11	130,800	10,566,000	80.0	Rural, Green Mountain, Early Ohio, Burbank, Irish Cobbler
Missouri	16	98,200	6,926,400	70.2	Early Ohio
Indiana.	19	82,600	6,521,000	78.2	Rural, Green Mountain, Early Ohio, Irish Cobbler

West. While none of the five are large producers of potatoes, as compared with the six leading states of this division, they nevertheless are, as will be noted in the above table, well up in the list, ranking between eight and nineteen, inclusive. A study of the yield per acre column shows that three of the five states are identical, 78.2 bushels, while the Iowa average is 80 bushels and Missouri only 70.2. It is evident, therefore, that the general climatic and soil conditions must be more or less similar.

Production Centres.—The chief producing centres in Ohio are, according to Ballou,[2] the counties of Portage, Wayne, Medina, Cuyahoga, Hamilton, Stark, Lucas, Summit, Erie, and Mahoning. He further states that, if the state be roughly divided into four quarters, it would be found that the northeastern quarter produced over one half the total crop of the state. In Illinois, the chief centres are located in Cook, Saint Clair, Madison, Whiteside, and Winnebago Counties. In Iowa, the leading counties are Grundy, Scott, Tama, Marshall, Mitchell and Pottawattamie. The Missouri centres of production, so far as counties are concerned, are St. Louis, Bay, Buchanan, Jackson, and Andrew. Those of Indiana are La Porte, St. Joseph, Allen, and Elkhart.

Cultural Practices.—Relatively little commercial fertilizer is used in the production of potatoes throughout these five states. In northern Ohio, according to Green,[3] the first two weeks in May is considered the most suitable time to plant. In northern Indiana, Illinois, and Iowa, the planting date for the late crop is similar to that of Ohio. Potatoes intended for early market might be planted considerably earlier. The planting date in the southern portion of these three states is at least three weeks earlier. In Missouri, the planting date in the northern portion is similar to that of the southern part of the preceding states, while in the southern portion, the planting date is advanced to March. In fact, in some localities, Essex, for example, the growing season is sufficiently long to permit of growing a second crop. In such cases, the early crop may be planted the latter part of February.

Modern machinery is generally used in planting, cultivating, and harvesting the crop. Level culture, rather than ridging, is almost universal. Spraying, except for insect pests, is not a general practice.

Markets.—With the exception of Ohio and Iowa in years of high production none of these states produce enough potatoes for home consumption; their markets are local rather than foreign, as the crop is, theoretically at least, entirely consumed within their own boundaries. It is quite probable that this group of states will continue to depend upon outside sources for a portion of their table stock supply. At present, they are dependent upon outside sources, largely Michigan, Wisconsin, and Minnesota, for a portion of their seed stock, and the probability is that still greater dependence will be placed upon these states.

Michigan, Wisconsin, and Minnesota.—This trio of states possess approximately the same climatic and soil conditions. They are large potato producers and are capable of very materially increasing their output whenever there is a market for it. In total production, Michigan, Wisconsin, and Minnesota rank second, third, and fourth. Sometimes one or other of them forces New York to take second place. The only widely known potato territory in this group of states is that of the Red River Valley in Minnesota. Other large shipping sections aside from the Red River Valley in Minnesota are Elk River, Princeton, Anoka, etc. In Wisconsin, the central portion of the state including Waupaca, Portage, and Waushara Counties, represented the largest producing centres in 1909, but for the next ten years or more, the commercial potato belt has been constantly moving northward, keeping pace as it were, with the subjugation of the cutover timber lands in not only Wisconsin but the other two states as well. A large portion of this type of land seems to be admirably adapted to clover and potatoes. In fact, clovers grow so naturally and luxuriantly throughout most of this section that it has been very happily designated "Cloverland." The commercial potato development of the future, in the "Middle West," is almost certain to be very largely centred in "Cloverland." Michigan has no outstanding potato district.

Extent of the Crop.—The production of these three states can be more easily comprehended from the data presented in the table which gives the annual yields for the ten years, 1910 to 1919 inclusive.

A comparison of these data show that Michigan's average production for the ten-year period is a trifle over 31 million bushels, Wisconsin 29.8, and Minnesota nearly 27 million bushels. The most interesting feature of these data is that of the wide fluctuations in yield from year to year with a relatively small fluctuation in acreage. In Michigan, extremely low yields prevailed during the years 1915 and 1916. Wisconsin's low mark came in 1916, while Minnesota shows low yields in 1910 and 1916. These low yields were due to unfavorable climatic conditions.

Varieties Grown.—The varieties grown in this area are mainly the Irish Cobbler, Early Ohio, and Triumph, for early varieties, and the Green Mountain, Rural, and Russet Rural, for late. Other varieties, grown to a lesser extent are the Pearl, King, Burbank, *Total and Average Acreage and Yield in Bushels for the Years 1910-1919.*

Year	MICHIGAN			WISCONSIN			MINNESOTA		
	Acreage	Total bushels	Bushels per acre	Acreage	Total bushels	Bushels per acre	Acreage	Total bushels	Bushels per acre
1910...........	335,000	35,175,000	105	260,000	24,700,000	95	165,000	10,065,000	61
1911...........	330,000	31,020,000	94	280,000	32,480,000	116	225,000	25,875,000	115
1912...........	350,000	36,750,000	105	291,000	34,920,000	120	245,000	33,075,000	135
1913...........	350,000	33,600,000	96	295,000	32,155,000	109	275,000	30,250,000	110
1914...........	364,000	44,044,000	121	304,000	37,696,000	124	270,000	30,780,000	114
1915...........	335,000	20,945,000	59	298,000	25,926,000	87	285,000	30,210,000	106
1916...........	320,000	15,360,000	48	290,000	13,630,000	47	280,000	16,800,000	60
1917...........	378,000	35,910,000	95	307,000	34,998,000	114	300,000	33,600,000	112
1918...........	340,000	28,560,000	84	304,000	33,440,000	110	312,000	32,760,000	105
1919...........	326,000	28,688,000	88	300,000	28,200,000	94	300,000	26,100,000	87
Ave. 10 Yr.	342,800	31,005,200	90.4	292,900	29,814,500	101.8	265,700	26,951,500	101.4

and Russet Burbank. The Early Ohio is the most extensively grown early variety in Minnesota. In Wisconsin, a strong effort is being made to develop a large Triumph seed trade in the South and, as a natural result, Triumph acreage is on the increase. Michigan has no very well developed seed trade, and is not extensively engaged in the production of early potatoes, except to supply local markets.

Cultural Practices.—The cultural practices in vogue in Michigan, Wisconsin, and Minnesota do not differ essentially from the central group of states with respect to planting and tillage of the crop. Level culture is practised. As a rule, most growers use too small an amount of seed, 10 to 12 bushels, rather than 15 to 18. In some sections of these states, one still finds growers using the hill instead of drill method of planting potatoes. The rows are usually spaced 36 inches apart and the plants in the row from 24 to 36 inches apart, mostly 30 to 36 inches apart, the field being marked in both directions with a marker, after which it is planted with hand planters. The hill method of culture is usually found on the cheaper and less productive lands, and is largely practised in order to permit of cultivating the crop in both directions with horse implements, thereby doing away with hand labor.

North and South Dakota, Nebraska, and Kansas.—These four states are the western tier of the North and West division of 21 states. They are, in reality, the western states of this division. In point of production with other states, they rank as follows: Nebraska 13; North Dakota 17; South Dakota 18; Kansas 25. Relatively speaking they are not large producers, though as a rule, except possibly in Kansas, they produce more than enough for their own needs. The production by years from 1910 to 1919, as given in the table of this group, shows a very low average yield in Kansas as compared with the other states. Kansas also shows the widest percentage range between the highest and lowest acre yields. These four states are of interest, aside from their constituting the western tier of states of the North and West division, in that certain sections of all of them can be irrigated. Irrigation plays a more important rôle in commercial potato production in northwestern Nebraska and southwestern South Dakota than in North Dakota and Kansas.

Potato Production Centres.—The chief production districts in

Total and average acreage and yield in bushels for the years 1910 to 1919

Year	Nebraska			North Dakota			South Dakota			Kansas		
	Acreage	Total bushels	Bushels per acre	Acreage	Total bushels	Bushels per acre	Acreage	Total bushels	Bushels per acre	Acreage	Total bushels	Bushels per acre
1910	110,000	6,600,000	60	35,000	1,435,000	41	55,000	2,420,000	44	88,000	5,016,000	57
1911	116,000	6,032,000	52	42,000	5,040,000	120	56,000	4,032,000	72	80,000	1,760,000	22
1912	118,000	9,440,000	80	52,000	6,656,000	128	62,000	6,510,000	105	70,000	5,740,000	82
1913	118,000	5,664,000	48	60,000	5,100,000	85	60,000	4,680,000	78	73,000	2,920,000	40
1914	118,000	9,440,000	80	70,000	7,630,000	109	63,000	5,670,000	90	72,000	4,464,000	62
1915	110,000	11,550,000	105	80,000	7,200,000	90	68,000	7,820,000	115	71,000	5,893,000	83
1916	105,000	7,665,000	73	75,000	6,975,000	93	65,000	4,290,000	66	70,000	4,970,000	71
1917	147,000	12,495,000	85	90,000	3,870,000	43	80,000	7,200,000	90	78,000	4,446,000	57
1918	121,000	10,406,000	86	92,000	9,108,000	99	95,000	8,645,000	91	80,000	4,240,000	53
1919	115,000	6,325,000	55	90,000	5,670,000	63	90,000	4,500,000	50	68,000	5,168,000	76
Average	117,800	8,561,700	72.7	68,600	5,868,400	85.5	69,400	5,576,700	80.4	75,000	44,617,000	59.5

Nebraska are in the northwestern section. The leading counties are Scottsbluff, Sheridan, Box Butte, Douglas, and Sioux. During the past two years, the Kearney district has come into considerable prominence as an early market production centre. South Dakota has no well defined area. The leading counties are Brown, Minnehaha, Spink, Brookings, and Day. The Red River Valley district on the eastern border of North Dakota, with Grand Forks and Larimore as the centre, is the chief commercial potato production centre of that state. The chief producing centre in Kansas is the Kansas or Kaw River Valley extending from Kansas City to Topeka. The leading counties are Wyandotte, Johnson, Leavenworth, Douglas, and Jefferson.

Varieties Grown.—The varieties grown in a commercial way are quite similar to those grown in the states to the East. They are as follows:

North Dakota	*South Dakota*	*Nebraska*	*Kansas*
Early Ohio	Early Ohio	Early Ohio	Early Ohio
Irish Cobbler	Irish Cobbler	Triumph	Irish Cobbler
Triumph	Triumph	Pearl	Triumph
Rural	Rural	Rural	Gold Coin
Green Mountain		Russet Rural	
		Charles Downing	

The Early Ohio is the leading variety in the eastern portion of these four states. The Triumph is of greatest importance in northwestern Nebraska, where it is being grown rather extensively for seed purposes on both dry and irrigated land, largely the former. This seed stock finds a ready market in Louisiana, Texas, Oklahoma, Arkansas, and other southern points.

Cultural Practices.—Where irrigation is not practised, level cultivation with a slight ridging with last cultivation is the usual method. When grown under irrigation, the ridge culture method becomes a necessity because it provides the only feasible way of irrigating the crop. The usual distance between the rows is three feet, but in some sections a wider spacing is allowed, this being particularly true under dry land culture. Owing to the almost if not complete absence of the late blight fungus in this region, few, if any, growers practise spraying their crop, except with arsenical poisons, as a protection against insect pests. The crop, as a whole, is largely grown for table stock, intended for fall and winter consumption and for seed purposes, rather than for the early market. The Early Ohio of the Red River Valley is marketed for seed purposes in eastern Nebraska, Kansas, and points East.

The Far-Western States.—The eleven states included in the geographical division known as the Far-Western States are Wyoming, Colorado, New Mexico, Arizona, Nevada, Utah, Montana, Idaho, Oregon, Washington, and California. Of these, California, Colorado and Washington are the largest producers; Arizona and New Mexico the smallest. Colorado has the distinction of being the heaviest shipper of potatoes to markets outside of her own borders. In all of these states, potatoes are grown both under irrigation and dry land conditions. In the Pacific Coast states, particularly Washington and Oregon, the climatic condition, so far as precipitation is concerned, is very similar to that in the northeastern United States.

The data presented in the table of this group show the average acreage yield in bushels, and bushels per acre of each of the far-western states for the years 1910 to 1914, 1915 to 1919, and 1910 to 1919. This summary shows that California leads in production in both five-year periods, but does not lead in bushels per acre. Nevada ranks first in yield per acre, with Utah and Idaho close rivals for second place. Too great importance should not, however, be attached to the relative yields per acre in the various states, as this is very largely influenced by the per cent of the acreage that is under irrigation. Take Colorado, for example, where quite a large acreage is grown under dry land conditions, the yields may vary from 50 to 150 bushels per acre. The same seed stock, under average conditions, would produce from 300 to 400 bushels on irrigated land. In fact, yields of over 500 bushels per acre have been frequently obtained on rather large acreages, both in Colorado and elsewhere. It is necessary, therefore, to remember, when comparing yields from one state with those from another, that the cnly true basis of study is that of comparing the irrigated sections. In the absence of complete data, regarding the actual acreage in each of the far-western states of irrigated and non-irrigated potatoes, it is not possible to make such comparison.

Varieties Grown.—While the list of varieties grown in these states is somewhat larger than is now regarded as good commercial practice, the actual number grown in any given section is not really a large one.

Average Acreage and Yield in Bushels for the Years 1910-1914, 1915-1919, and 1910-1919.

STATE	YEARS 1910-1914			YEARS 1915-1919			YEARS 1910-1919		
	Acreage	Bushels	Bushels per acre	Acreage	Bushels	Bushels per acre	Acreage	Bushels	Bushels per acre
California	71,000	9,272,400	130.6	87,200	12,032,400	136.2	79,100	10,652,400	134.7
Colorado	78,600	7,137,000	90.8	72,800	10,049,000	138.0	70,700	8,593,000	121.5
Washington	57,000	8,167,400	143.2	64,200	8,715,200	135.7	60,600	8,441,300	139.3
Oregon	50,800	6,435,600	126.7	54,600	6,320,000	115.7	52,700	6,377,800	121.0
Idaho	31,200	5,230,600	167.6	32,800	5,064,800	154.1	32,000	5,147,700	160.9
Montana	32,400	4,675,000	144.3	46,400	5,181,000	111.7	39,400	4,928,000	125.1
Utah	17,800	2,829,000	158.9	20,000	3,288,800	164.4	18,900	3,058,900	161.8
Wyoming	11,800	1,268,400	107.5	25,600	3,336,000	130.3	18,700	2,302,200	123.1
Nevada	9,400	1,467,200	156.1	11,400	2,089,000	183.1	10,400	1,778,100	170.9
New Mexico	7,800	661,000	84.7	9,600	877,400	91.4	8,700	769,200	88.4
Arizona	1,000	101,000	100.1	3,200	262,000	81.9	2,100	181,500	86.4

The accompanying list of varieties, submitted for each state, is believed to include most of those that are more generally grown commercially:

Arizona.—Triumph.

California.—Burbank, Russet Burbank, White Rose, Chas. Downing (Idaho Rural), Early Rose.

Colorado.—Pearl, Rural, Russet Burbank, Brown Beauty, Chas. Downing, Perfect Peachblow (Red McClure), Early Ohio, Irish Cobbler.

Idaho.—Chas. Downing, Rural, Russet Burbank, Early Ohio.

Montana.—Rural, Green Mountain, Russet Burbank, Pearl, Irish Cobbler, Triumph, Early Rose, Early Ohio.

Nevada.—Rural, Burbank, Russet Burbank, Pearl (Peerless), Perfect Peachblow, Early Ohio.

New Mexico.—Irish Cobbler.

Oregon.—Burbank, Pride of Multnomah, Russet Burbank, White Rose, Early Ohio.

Utah.—Chas. Downing, Rural, Russet Burbank.

Washington.—Burbank, Russet Burbank, Chas. Downing, Rural, Early Ohio.

Wyoming.—Pearl, Chas. Downing, Russet Burbank, King.

Production Centres.—Generally speaking, the west and far-western states have more clearly defined production centres than in the East. This is due to the fact that a large per cent of the crop is grown under irrigation and is therefore confined to these areas.

Colorado.—In Colorado, the potato industry is roughly segregated into seven districts known as the Greeley, Divide, Northwestern, Intermountain, Western Slope, Southwestern, and the San Luis Valley. The Greeley district, located in Weld County, is so well known that little need be said regarding it. Until the year 1909, it had always enjoyed the distinction of being the largest production centre in the state, and prior to 1910 was considered the second largest potato-producing section in the United States. In 1909, 10,000 carloads of potatoes were shipped out of the county; and the 1910 census report, based on the 1909 crop, credits Weld County with a production of 5,857,691 bushels, an amount in excess of the total production of seven of the eleven states included in the far-western group. Unfavorable weather conditions, accompanied by a severe epidemic of potato diseases during the years 1910 to 1914, very nearly wiped out the industry commercially. Since 1914, there has been a gradual improvement in conditions, and the district is rapidly coming back into its own as a commercial potato-producing centre.

The Divide district includes portions of three counties, Douglas,

Fig. 66.—A field of Russet Burbank (Netted Gem) potatoes on the Crystal River Land Co. ranch, Carbondale, Col. This 65 acre field yielded at the rate of 500 bushels per acre. Courtesy of Lou D. Sweet.

Elbert, and El Paso. It occupies the elevated central section of the "Eastern Slope" of the Rockies. The rainfall of this district, particularly of the more elevated portions which reach an altitude of 7,500 feet, is sufficiently heavy, nearly 20 inches, to permit of growing a crop of potatoes without irrigation. This is made possible by a cool summer climate, which furnishes ideal conditions for the production of good seed potatoes. About 3,000 acres of potatoes are grown in the district.

The Northwestern district is of relatively little importance commercially. It includes portions of Moffat and Routt Counties, located in the extreme northwestern part of the state. The climatic conditions are very similar to those of the Divide section. The Early Ohio and the Russet Burbank are the leading varieties. The area devoted to potatoes is about 750 acres.

The Intermountain district is generally referred to as the Carbondale district, but this is somewhat erroneous, as it also includes the Eagle River district. These are located in Garfield and Eagle Counties, respectively. Owing to the relatively high altitude of the intermountain district, 6,000 feet and above, the climatic conditions are very favorable to potato production. Both the Eagle and Carbondale districts have an abundant supply of irrigation water drawn from the Eagle and Crystal Rivers. The leading varieties are the Russet Burbank (Fig. 66), Peachblow (Fig. 67), Rural, and Charles Downing. The total area devoted to the potato is about 5,500 acres. The Crystal River Land Company, generally referred to as the Sweet Ranch, has long enjoyed an enviable reputation in the production of large per acre yields. The present and former associate proprietors are shown in figures 68 and 69.

The Western Slope district embraces the valleys of the Grand, Gunnison, and Uncompagre Rivers, and the adjacent irrigated mesas. Portions of Mesa, Delta, and Montrose Counties are included in this district. The leading varieties are Irish Cobbler, Charles Downing, People's, Russet Burbank, and Rural. Over 6,000 acres of potatoes are grown in this territory.

The Southwestern district consists of the irrigated valleys and mesas of Montezuma and La Plata Counties. The comparative unimportance of the potato industry of this section is largely due to poor shipping facilities. The soil and climate is well suited to potato production. The leading varieties are Early Ohio, Russet Burbank, and Rural. Acreage 2,000.

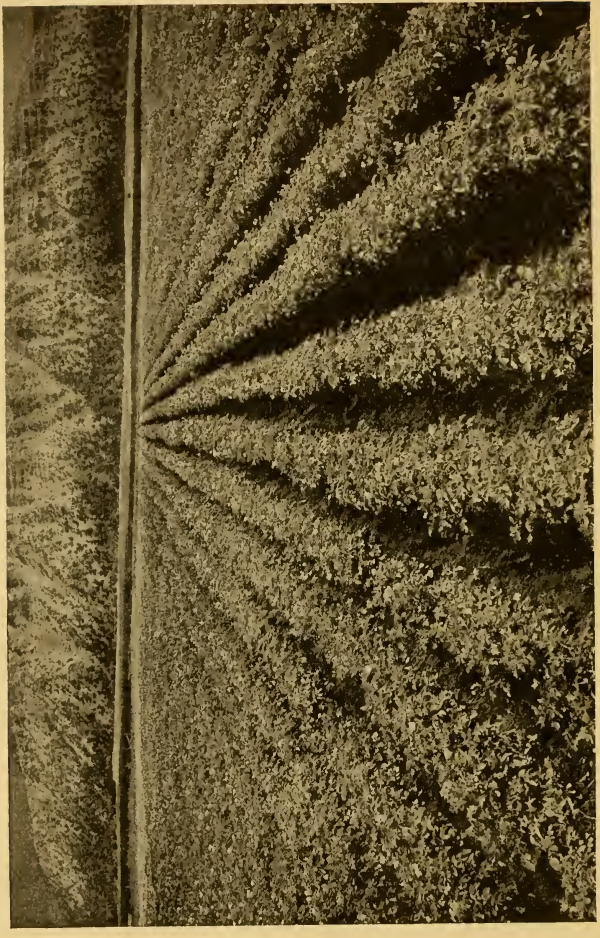

FIG. 67.—Seed plot of the Perfect Peachblow planted first week in July, 1913. Crystal River Land Co., Carbondale, Col. Courtesy Lou D. Sweet.

The San Luis Valley district enjoys the distinction of having produced a larger crop of potatoes in 1919 than the Greely district, and there is a possibility of its ultimately becoming the leading production centre in the state. This elevated plain, with altitude at some points exceeding 7,500 feet, is located in the south central portion of the state. The larger portion of the potato-producing section is in Rio Grande County. Most of the area is irrigated. The leading varieties are Brown Beauty, Russet Burbank, Early Ohio, People's, and Rural.

District Shipments.—The accompanying data, furnished by the Bureau of Markets of the United States Department of Agriculture, gives a fairly good idea of the relative importance of the principal shipping districts for the years 1917, 1918, and 1919.

District	*1917*	*1918*	*1919 estimate**	*Normal estimate*
Greely	5,977 cars	5,740 cars	2,500 cars	6,000 cars
San Luis Valley	2,948 cars	3,562 cars	4,400 cars	4,000 cars
Gunnison Delta and Montrose	2,380 cars	2,498 cars	2,200 cars	2,500 cars
Carbondale above Glenwood Spgs. on Roaring Fork	663 cars	693 cars	525 cars	600 cars
Eagle above Glenwood Spgs. on Main	534 cars	463 cars	400 cars	500 cars
Grand Junction	567 cars	516 cars	400 cars	500 cars
San Juan	104 cars	46 cars	65 cars	75 cars
Moffat	112 cars	64 cars	100 cars	100 cars
Miscellaneous Ft. Collins Dry Land	379 cars	157 cars	135 cars	175 cars

* Estimated number of cars that would be shipped. 1917 and 1918 data represent actual shipments.

Wyoming.—The potato industry of Wyoming is a relatively small one, and is largely restricted to the irrigated portions of the state. There are no very large producing centres. The leading counties, as shown by the 1909 census data, were Laramie, Bighorn, Sheridan, Crook, and Carbon, with yields ranging from 203,016 bushels in Laramie County to 64,378 bushels in Carbon County. Torrington, in Goshen County, is the centre of one of the more recently developed irrigation areas in Wyoming. The land in the vicinity of Torrington seems to be admirably adapted to the potato. Some fields visited in 1918 promised to yield around 250 sacks (approximately 500 bushels). A considerable acreage of potatoes was grown in the Cowley drainage district in Park County in 1919,

Fig. 68.—Lou D. Sweet, Carbondale, Col. A well known authority on potato culture. President of the Crystal River Land Co., better known as the Sweet Ranch, on which high yielding crops of potatoes are annually produced.

Fig. 69.—Frank E. Sweet, Carbondale, Col. A successful potato grower and former partner of Lou D. Sweet of the Crystal River Land Co.

and it is claimed that there will be a large increase in 1920, due to the installation of a modern dehydration and starch factory at that point.

Varieties.—The leading varieties grown in the state are the Pearl, Spaulding No. 4 (King), Charles Downing, and the Russet Burbank (Netted Gem).

Montana.—The average total production of potatoes in Montana during the ten-year period 1910 to 1919, inclusive, was slightly less than 5 million bushels, with an average acre yield of 125.1 bushels. There are no extensive production centres. A considerable acreage of potatoes is grown in the Flat Head Lake region.

Varieties.—The principal varieties grown are Rural New Yorker No. 2, Burbank, Russet Burbank, Green Mountain, Pearl, Early Ohio, Triumph, and Irish Cobbler.

Idaho.—The potato crop of Idaho slightly excels that of Montana both in total yield and in production per acre. This is probably due to the fact that a larger proportion of Idaho's potato crop is grown under irrigation than that of Montana. The average production for the ten-year period 1910 to 1919 was 5,147,700 bushels, and the average acre yield was 160.9 bushels. Idaho has several distinctive and well recognized production centres. These are in the order of their importance, the Idaho Falls, Burley, Boise or Caldwell, Blackfoot, and Twin Falls irrigation sections.

In the Idaho Falls district there are large tracts of warm, sandy soils, irrigated with water taken from the Snake River. No attempt is made in this section to produce an early market crop. The varieties most largely grown are the Russet Burbank and the Rural New Yorker.

The Caldwell district on the Boise project is of considerable importance as an early market section. The soil is for the most part a light sandy loam, well adapted to the production of an early crop. The variety grown is the Charles Downing or, as it is more generally known in this section, the Idaho Rural. It is a second-early or mid-season variety, but seems well adapted to its environment in this region. The growers hasten its maturity by withholding irrigation during early July in order to ripen off the vines and harden the skin. They begin to dig the crop the latter part of July or early August and it should all be marketed before August 25. Owing to a combination of circumstances, some growers sustained rather heavy losses in 1919, due to the scalding of the potatoes in the ground as a result of their not having been marketed soon enough. On September 10, the writer saw one field in which the grower had sorted out fully 50 per cent of the crop, and the other 50 per cent failed to pass inspection as No. 1 stock. Failure to market the crop at the proper time was due to a shortage of refrigerator cars in which to transport the stock, and to the scarcity of labor, thus delaying harvesting operations.

The Burley district is the second most important potato production centre in Idaho.

The Blackfoot and Twin Falls districts are of much less importance from a commercial standpoint. The only drawback to a large production of potatoes in Idaho is that of its distance from the large consuming centres.

Nevada.—Although the State of Nevada produces a comparatively small crop considering its geographical area, it is relatively large when based upon its population. The average production for the past ten-year period, 1910 to 1919, was 1,778,100 bushels, while the population of the state, as reported in 1915, was 106,734. On this basis, the per capita production was about 16⅔ bushels. When this amount is compared with the per capita production of the leading potato-producing state in the Union of 3.4 bushels, it is seen that Nevada's crop far outranks that of New York State, in point of population at least. Hardman states[4] that less than 2 per cent of the total cultivated area of the state is devoted to potatoes, and that, of the 900,000 acres of irrigated land, about 15,000, or 1⅔ per cent were devoted to the potato crop. The average production per acre of 170.9 bushels gives Nevada second place among the states of the Union, Maine alone surpassing her in this respect.

Principal Potato Districts.—The principal potato-producing districts, four in number, located in the western portion of the state, are as follows: (1) Truckee valley; (2) the Newlands Reclamation Project; (3) the Carson valley; (4) the Mason valley. According to Hardman, large areas of the Newlands Reclamation Project, and the Mason valley are excellently adapted to potato culture.

Date of Planting.—The bulk of the crop is planted during the middle of May, and is generally completed by the first of June.

Varieties.—The principal varieties grown are the Rural New Yorker No. 2, Burbank, Russet Burbank, Pearl, Early Ohio.

Arizona.—The state of Arizona has the distinction of being the tail-ender in potato production. Its average annual production for the ten-year period, 1910 to 1919, is only 181,500 bushels with an average acre yield of 86.4 bushels. Potato production in the state at the present time is on the increase. In fact, the Bureau of Crop Estimates' statistics note an acreage increase of 500 per cent since 1916. A small industry is being developed near Flagstaff, in Coconino County, and Glendale, in Maricopa County.

In the southern part of the state, the early crop is planted from January 15 to February 15; and the fall crop, from August 20 to September 10. The early crop must be out of the ground before

July 1, as it deteriorates very rapidly with the advent of extremely hot summer weather. The early crop is usually consumed before July 4.

New Mexico.—Potato growing in New Mexico is a rather unpromising industry, owing to the many failures that are incurred through the non-development of marketable sized tubers. These failures usually occur in hot dry seasons, and are, in most cases, probably entirely due to unfavorable climatic conditions. In some cases, fungous diseases inhabiting soils, such as Fusaria and Rhizoctonia, are no doubt responsible for lack of success in producing a profitable crop of potatoes. The annual production during 1910 to 1919 was 769,200 bushels with an average yield per acre of 88.4 bushels. The largest production centre is Cloudcroft in Otero County. The Irish Cobbler is the principal early variety.

Neither New Mexico nor Arizona are ever likely to become important potato-producing states.

Utah.—The State of Utah ranks seventh in point of production among the eleven far-western states. Utah, Davis, Salt Lake, Cache, and Weber Counties are the largest production centres. The average annual production during the period of 1910 to 1919 was 3,058,900 bushels, with an acre yield of 161.8 bushels.

The principal varieties grown are the Charles Downing (Idaho Rural), Russet Burbank, and Rural New Yorker No. 2.

Oregon.—The State of Oregon has two rather distinctive types of climatic conditions, the eastern portion having a practically semi-arid climate, while the western portion has a more or less humid one. The average annual production of the state for the years 1910 to 1919 was 6,377,800 bushels with an average acre yield of 121 bushels. The largest production centres are located in Multnomah, Marion, Clackamas, Washington, Lane, and Lincoln Counties.

The leading varieties grown are the Pride of Multnomah (Burbank type), Russet Burbank, White Rose, Early Ohio, Rural New Yorker No. 2 and American Wonder (Burbank type).

Washington.—The climatic conditions in Washington State are very similar to those in Oregon, in that the western portion is humid and the eastern part semi-arid. There are two rather well recognized irrigated sections, the Yakima and Wenatchee Valleys, which produce considerable quantities of potatoes. The average annual production of the state for 1910 to 1919 was 8,441,300 bushels with an acre yield of 139.3 bushels. The leading production centres are located in Yakima, Spokane, Skagit, King, and Whitman Counties.

The leading varieties are the Russet Burbank, Charles Downing, Early Ohio, and Rural New Yorker No. 2.

California.—The state of California enjoys the distinction of having a greater variety of climatic conditions than any other state in the Union. In the southern portion of the state, it is possible to produce a crop of potatoes about as early as in southern Florida; while in the more elevated portions of the northern part, the frost-free season is hardly of sufficient length to permit of maturing a crop. It is not strange, therefore, that many problems confront the California potato grower. In point of production, California leads all others of the far-western states, with an average annual yield for the years 1910 to 1919, of 10,652,400 bushels, and an acre production of 134.7 bushels. The chief production centres are San Joaquin, Los Angeles, Sacramento, Contra Costa, and Santa Cruz Counties. Of these centres San Joaquin and Los Angeles are the most important. The potato crop in San Joaquin County is produced on the reclaimed "tule" lands in the delta sections of the San Joaquin and Sacramento rivers.

First crops on reclaimed lands will frequently run 300 sacks per acre. The sack will average about 115 pounds. In Los Angeles County it is possible to plant potatoes for the early market during January, and to harvest the crop in the latter part of March and early April. A second crop, planted in late July or August, is also grown in this section, and is harvested in November.

The Potato King.—The story of the Stockton potato district, San Joaquin County, would not be complete were we to fail to mention the "potato king," of the Pacific Coast, Mr. George Shima, who, not so many years ago, emigrated to California from Japan and became a day laborer on these reclaimed lands. The story of his rise from a day laborer to the largest potato grower and potato operator on the Pacific Coast is one which should thrill every ambitious American youth. Some years ago, Mr. Shima was growing 8,000 acres of potatoes. The writer was on one tract of 4,400 acres, in the spring of 1910, which was being fitted for planting to potatoes by Shima's crew of laborers.

Harvesting the Crop.—The usual method of digging the crop is with a heavy five or six-pronged hoe fork, so constructed as to be used in the same manner as a hoe. Each digger picks up the tubers as they are dug. Large and strongly made wicker baskets serve as containers for the tubers. When full, the contents of the basket is transferred to a two-bushel burlap bag. The sacks are well-filled, and the digger usually faces the mouth of the sack with extra large and well shaped tubers. When the market is dull at digging time and the stock grown is sound, it is frequently stored in large piles on the levee and covered with "tule" grass, to protect the tubers from the light frosts that occur in this region during the winter season, and from light. A large proportion of the crop is moved to the market in boats in much the same manner as in the Norfolk district, though the Stockton district is practically all accessible to water.

QUESTIONS ON THE TEXT

1. Why does the potato succeed best in the northern part of the temperate zone?
2. What bearing has altitude on potato production?
3. What are the leading potato-producing states?
4. What percentage of the crop is produced by the six leading states?
5. What are the two important factors affecting heavy or light production?
6. How does the average production per acre of the far-western states compare with that of the six heavy producing states?
7. How does the production of Aroostook County, Maine, compare with the total production of other states? Explain this.
8. What is the general character of the soil of Aroostook County, Maine?
9. What are the leading commercial varieties grown in Maine? Secondary varieties?
10. Is there any similarity between the Long Island, N. Y., and the New Jersey districts? What is it?
11. What are the chief points of differences between these two districts and that of northern Maine?
12. What are the leading varieties grown in these districts?
13. What are the chief producing centres in New Jersey?
14. What is the chief production centre on Long Island, N. Y.?
15. What is the character of the soil in the more intensive potato-producing areas on Long Island and in New Jersey?
16. How do the climatic conditions of these compare?
17. What is the source of seed supply of these two sections?
18. Do the New England States, Maine excepted, produce any considerable quantity of seed potatoes? Why?
19. Are early varieties grown to any considerable extent in western New York and Pennsylvania? Give reason.
20. What does a comparison of production in these two states for the years 1910 to 1919 show?
21. What varieties are most commonly grown?
22. What did Stone's investigations with level and ridge culture disclose?
23. How do they store their crop of potatoes?

24. Of what importance are the States of Ohio, Indiana, Illinois, Iowa and Missouri from the production standpoint?
25. Compare their yields per acre with Long Island.
26. Name some of the larger producing counties in Ohio.
27. What are the leading counties in Illinois?
28. What are the leading counties in Iowa?
29. What are the leading counties in Missouri?
30. What are the leading counties in Indiana?
31. What can you say regarding the use of commercial fertilizers in these five states?
32. What is the common system of culture?
33. Where do they usually market their crops?
34. On what states are they largely dependent for their seed stock?
35. In what respects are Michigan, Wisconsin and Minnesota quite similar as regards potato production?
36. What are the distinctive and widely known potato districts in these states?
37. What is the most interesting feature relative to the annual production of these states?
38. What are the leading commercial varieties grown in these states?
39. What can be said of the seed trade in these states?
40. What are the cultural practices in this group of states?
41. Discuss the yields of each of the next group of states.
42. What special interest have these four states over those previously considered?
43. What are the chief production sections in each?
44. What are the leading commercial varieties in these states?
45. In what part of each of these states is the Early Ohio grown?
46. In what state is the Triumph most extensively grown? Where sold for seed?
47. Name the eleven far-western states.
48. Which are the largest producing states?
49. What particular distinction does Colorado possess?
50. What two classes of potato production do we have in these states?
51. What similarity is found in Washington and Oregon to that of the north-eastern United States?
52. Which of the eleven states leads in total production per acre and which in average bushels per acre?
53. What are the leading commercial varieties in Arizona and New Mexico?
54. What are the leading commercial varieties in California and Colorado?
55. Name some of the potato districts in Colorado.
56. Of what importance is the potato industry in Wyoming?
57. What was the average production of Montana during the ten-year period 1910 to 1919?
58. What are the principal varieties grown?
59. What is the extent of the Idaho crop?
60. What is the special feature of interest regarding the Caldwell district?
61. Of what relative importance is the potato crop of Nevada?
62. Compare its per capita production with that of New York.
63. What percentage of the cultivated area of the state is devoted to potatoes?
64. What is the average production per acre?
65. Discuss potato growing in Arizona.
66. Discuss potato growing in New Mexico.
67. Give annual production, leading counties and varieties for Utah.

68. Give the annual production, largest centres and leading varieties.
69. Name two well recognized irrigated districts in the state of Washington.
70. Give the average annual production, leading counties and varieties of Washington.
71. For what is the state of California noted climatically?
72. Discuss its production and chief centres.
73. How many sacks per acre do they sometimes harvest from newly reclaimed land?

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CHAPTER XI

POTATO PRODUCTION COSTS

Business Principles.—The successful conduct of any manufacturing enterprise is, in a large measure, dependent upon two factors: (1) Low cost of production consistent with the manufacture of a good article; and (2) the successful merchandising of the manufactured product. If we regard the farmer as a manufacturer of raw food products, or at least as an instrument to that end, then we may regard the production of potatoes in the same light as that of the manufacture of potato machinery, in that the same general business principles apply to each. In fact, there are greater opportunities for the exercise of good judgment and the intelligent application of modern principles of agriculture in the manufacture, if we may so employ the term, of a crop of potatoes than in the building of the most complicated implement used in the potato industry. The manufacturer of the latter has complete control of all the factors involved in the construction of such an implement; while in the case of the potato grower or manufacturer, there are at least two factors, temperature and moisture, over which he can exercise little or no control, unless he is fortunate enough to be located in an irrigated section, thereby making it possible to supply moisture. In Chapter IV, an attempt is made to show how the grower may modify unfavorable temperature and moisture conditions; hence no further attention need be given to these factors.

Cost Per Acre Misleading.—In most discussions dealing with the cost of producing potatoes, greater stress has been laid upon the production cost per acre than on the cost per bushel or per pound. The statement that it cost \$150, \$175, \$200 or \$225 to grow an acre of potatoes may mean much or little, according to whether it carries with it the additional information as to the yield obtained in each case. The man who grew an acre of potatoes for \$150 and only produced 150 bushels, cannot be regarded as successful as one whose acre cost was \$225 and production 400 bushels. In the first instance, the actual cost per bushel was \$1.00, while in the latter, it was only \$0.5625. A comparison, therefore, of production costs per acre affords no conclusive evidence of the actual cost per bushel, unless accompanied by the further information as to the yield obtained.

Cost Factors in Potato Production.—In arriving at a proper and fair cost basis in the production of an acre or a bushel of potatoes, it is necessary to determine what items of cost should be properly charged against the crop. These may be roughly grouped under nine heads, *viz.*: (1) labor; (2) materials; (3) interest; (4) insurance; (5) taxes; (6) depreciation; (7) overhead; (8) risk; (9) miscellaneous items. Under the first head would be included hand and horse labor necessary to the plowing and fitting of the land, the application of fertilizers, seed cutting, planting, cultivation, spraying, harvesting, storing, grading and marketing of the crop. The second head includes the cost of the chemical fertilizers or farmyard manures applied to the land, seed, spray materials, and containers used in marketing the crop. The third charge represents interest on investment, which should include not only the land, but every implement and building or storage space used in handling the crop. Too often this charge only applies to the land. Insurance applies to equipment, storage house, and the crop itself when stored for winter or spring marketing. Taxes are self-explanatory; they represent the actual assessments on real estate and personal property involved in the production of the crop. Depreciation in the value of implements used in the growing of potatoes should be based on the average life, if we may so term it, of each. If, for example, this average life is 300 acres of potatoes, then one-three-hundredth of the value of the implement should be charged against each acre. In the case of the seventh item, a slightly different problem is presented. This is a charge which is generally overlooked by the grower in determining his production costs. In all manufacturing establishments, overhead expenses is one of the most important items in production costs. There is no good reason why the producer of agricultural crops should not assess a fair charge against each crop over which he exercises supervision, instead of simply charging against the crop the actual hours of man labor devoted to the growing and handling of it. The producer should regard his services or his time as having a certain fixed value throughout the year, and all time not actually devoted to any crop should be pro-rated against each crop grown on the farm on the basis of the actual cost of producing such crops.

The potato crop should also bear its proportional share of the maintenance cost of horses or mules necessary to the proper operation of the farm, during that portion of the year in which they are idle; for example, rainy days, Sundays and in the winter season. Rainy days and Sundays may be taken care of through a high enough horse labor charge per hour or per diem, for actual work performed, but, as a rule, it is not completely covered by such charges. By risk is meant that element of uncertainty as to the extent of the crop that will be produced. The producer of agricultural crops is engaged in a business that is fraught with greater elements of risk than that of almost any other business enterprise, unless it be that of prospecting for oil or minerals. The potato crop is, perhaps, a riskier one to grow than any other food crop, because it is so easily affected by drought, heat and frost, fungous diseases, and insect pests. Any one of these conditions may seriously reduce the crop and render it a liability, instead of an asset, in the farm account book. It is believed that a certain fixed charge should be assessed against the potato crop each year as a provision against monetary loss. What such a charge should be must be determined for each locality. The prevalence of droughty or of high temperature periods during the growing season, or of serious outbreaks of late blight or other serious diseases, or of insect pests must be taken into consideration in arriving at a just and fair risk compensation. To the miscellaneous items account should be charged all expenses connected with the repairing of farm implements or of buildings used in the growing, handling, or storing or marketing of the crop. It should also include any other items of expense not specifically provided for under the other heads.

Average Production Cost.—Any attempt to present a set of data, which would adequately represent the average cost of producing a bushel of potatoes in the United States, or elsewhere, is obviously impossible; local conditions are so variable that such data would have little practical value except for the actual locality upon which the cost data was based.

In 1916, App [1] published the results of a rather comprehensive study of the relation of the potato crop to farm profits. In the pursuit of this study, App took data on the operating costs and income of some 370 potato farms. While, according to the author, (p. 68) no work was done to determine the actual acre and bushel cost of producing potatoes on the 370 farms, there were 25 of these farms from which practically nothing but potatoes were sold.

Potato production costs in certain sections of New York State, from data by Fox

Cost Factors	1912 Steuben County		1912 Suffolk County		1912 Nassau County		1913 Clinton and Franklin Cos.		1913, 1914 and 1915 26 records on 20 cost acc't farms	
	355 farms	5227.1 acres	161 farms	3149.7 acres	41 farms	1466.3 acres	300 farms	2160 acres	338.5 acres	
	Amount per acre	Cost per acre	Amount per acre	Cost per acre	Amount per acre	Cost per acre	Amount per acre	Cost per acre	Cost per acre	Amount per acre
Man labor	79.6 hrs.	$13.93	77.4 hrs.	$13.54	107.2 hrs.	$18.76	122.6 hrs.	$21.45	73.1 hrs.	$13.58
Horse labor........	85.0 hrs.	12.75	68.2 hrs.	10.23	116.2 hrs.	17.43	102.8 hrs.	15.43	74.5 hrs.	11.06
Seed	10.2 bu.	9.48	11.9 bu.	14.70	12.4 bu.	15.28	12.0 bu.	6.79	14.7 bu.	6.91
Manure	2.3 tons	4.80	0.36 tons	0.88	0.57 tons	1.68	4.3 tons	7.20		5.78
Commercial fertilizer	124.0 lbs.	1.66	1840.0 lbs.	28.01	1868.0 lbs.	30.76	407.0 lbs.	5.77	458.0 lbs.	5.58
Fungicides.........		0.08		0.62		2.48		0.22		0.92
Insecticides		0.12		0.68		0.72				
Land rental ...		3.00		12.81		15.78		3.00		4.47
Use of buildings ...		0.81		0.50		0.28		2.08		1.18
Use of equipment...		4.25		3.41		5.81		5.04		3.29
Miscellaneous items.		0.25		0.14		6.90		0.34		.00
Total cost		$51.13		$ 85.52		$113.51		$67.43		$52.78
Cost per bushel.....		0.42		0.54		0.617		0.3898		0.4202
Returns	121.7 bu.	53.59	157.6 bu.	111.18	187.0 bu.	140.16	179.3 bu.	$103.72	125.6 bu.	64.78
Profits		2.46		25.66		26.66		36.29		7.92

*Fox says the source of his data on potato production in Clinton and Franklin Counties was a thesis by W. M. Peacock in the Cornell University Library entitled "Factors influencing the cost of potato production in Clinton and Franklin Counties. New York."

The receipts, other than from potatoes, on these farms averaged less than 8 per cent, and in arriving at the actual cost per bushel or per barrel, App deducted this revenue from the total, thereby arriving at a figure which he believes to be quite representative of the production cost of potatoes in Monmouth County, New Jersey. His data shows a cost of 92 cents per barrel or 33 cents per bushel.

App's Cost Data.—The production costs given by App in the following table are, in his judgment, fairly representative of this section in 1914. They show a total production cost per acre of $85.15, and a total income of $123.48, leaving a net profit of $38.33 per acre. The average price received for the potatoes on these farms was $1.45 per barrel, and the average labor income of these farms was $2,123.00.

Acre cost of producing potatoes on 25 potato farms in Monmouth County, New Jersey.

Total acres of potatoes on the 25 farms	919
Labor expense per acre	$21.58
Cost of potato seed—485 bbl.	10.76
Fertilizer expense	24.95
Machinery depreciation	2.35
Spraying materials	0.51
Barrels	0.55
Clover crop seed	0.73
Taxes	3.10
Insurance	0.94
Interest	21.72
Grass seed per acre	0.92
Miscellaneous	7.62
Total acre expenses	$95.72
Brought forward	$95.72
Receipts from crops other than potatoes, divided by the number of acres of potatoes	10.57
Cost per acre of potatoes	$85.15
Yield per acre	92.1 bbl.
Cost per barrel	0.92
Cost per bushel	0.33

Fox's Cost Data.—One of the most exhaustive studies upon the cost of producing potatoes that has come to the writer's attention is that recently published by Fox,[2] in which a digest of the cost of producing potatoes on 355 farms in Steuben, 161 in Suffolk, and 41 in Nassau Counties in 1912; 300 in Clinton and

Franklin counties in 1913; and 26 records on 20 cost account farms in 1913, 1914 and 1915, is presented.

The following analysis of Fox's tables presents the more salient features of these data. The comparison of costs in the several localities from which his figures were secured is very interesting.

In studying these data, it is important to bear in mind that these costs were obtained in pre-war times, when the price of labor, fertilizer and all other factors entering into potato production were from 50 to 100 per cent less than in 1920. The small amounts of manure and commercial fertilizer used in Steuben, Clinton and Franklin Counties, is due to the fact that relatively few of the 655 farmers involved used either one or the other. The same thing is true with respect to the use of fungicides and insecticides. For example, Fox states that only 180 of the 355 Steuben County farmers sprayed their potatoes, and that Bordeaux mixture was only used on 17 farms. Peacock's (*l.c.*) data show that 203 of the 300 Clinton and Franklin County farmers sprayed their potatoes with arsenical poisons, and only three sprayed with Bordeaux mixture. An interesting feature of these data is that of the wide variation in the average cost of growing an acre of potatoes. The average cost in Steuben County being $51.13, as against $113.51 in Nassau County or an increase of 122 per cent. The cost per bushel varied from 37 to 61 cents or a difference of nearly 65 per cent. The significance of these figures is not fully appreciated until they are compared with their selling value. For example, the 355 Steuben County farmers produced potatoes on 5,227.1 acres at an average cost of $0.4201 per bushel; for which they received a return of $0.4403 per bushel, thereby netting a trifle over two cents per bushel, or a total return of $2.46 per acre. The 161 Suffolk County farmers, on their 3,149.7 acres, produced potatoes at an average cost of $0.5426 per bushel; for which they received a return of $0.7055 or a net profit of $0.1629. The total return per acre was $25.66. Nassau County growers, of whom there were 41 with an aggregate of 1,466.3 acres, grew potatoes at an average cost of $0.607 per bushel; for which they received a return of $0.7495, or a net profit of $0.1425 and a total return of $26.66. The 300 Clinton and Franklin County growers, on 2,160 acres, produced potatoes at an average cost of $0.3898; for which they received a return of $0.5784 per bushel, or a net total profit of $36.29 per acre. The average of the 26 records, from the 20 cost account farms, showed an actual cost of $0.4202 per bushel, with returns of $0.5158; or a net profit of $0.0956 per bushel, and a total profit of $7.92 per acre.

One of the most important economic lessons to be deducted from these data is that it was more profitable for the Nassau County farmers to produce potatoes at a cost of nearly 61 cents per bushel, than it was for the Steuben growers at 42 cents. This was made possible through the wide difference in price received for their crop by these two groups of growers. Had the Nassau growers been compelled to dispose of their crop at the same price as that received by the Steuben growers, they would have sustained an actual loss of $34.95 per acre, instead of realizing, as they did, a profit of $26.66. It is obvious from these data that low cost of production is not necessarily correlated with a large net profit per acre. Proximity to large consuming centres, where advantage can be taken of a strong market, may make potato production a more profitable undertaking, even at a greatly increased cost per bushel, than in a remote-from-market section, where the grower is more or less dependent upon local buyers for the disposal of his crop.

Pelton's Cost Data.—At a meeting of the Connecticut Vegetable Growers Association, in February, 1918, some cost figures on potato production, based on rather small areas, were presented by Pelton;[4] in which it was shown that, under Connecticut conditions, the cost of growing potatoes was greater on very small areas than on larger ones. Three sets of cost data were submitted, one being based on a half acre, another on one acre and the third on nine acres. These data, as assembled in the next table, show that it cost $132.16 to grow half an acre, or at the rate of $264.32 per acre; $171.55 for an acre; and $166.55 on a nine-acre basis. Striking variations in the cost of the same item in the three sets of data may be noted in this table. For example, in the digging and storing of the crop, the cost varies from $20.00 per acre on the nine-acre field to $46.50 on the acre field and $31.24 on the half acre, or at the rate of $62.48 per acre.

These figures are interesting in that they illustrate very forcibly the impossibility of producing potatoes cheaply on small areas where, of necessity, much of the labor must be performed by hand. It also emphasizes the fact that the small grower cannot successfully compete with the large grower, provided the latter uses modern machinery and handles his crop intelligently. Potato production on a small acreage basis with a large amount of man labor is only justifiable where the crop is primarily grown for family use, or where nearby markets absorb it at practically retail prices.

Nordman's Cost Data.—A rather recent article by Nordman[3] contains some interesting information upon the cost of potato

Cost of Potato Production in Connecticut in 1917, by W. C. Pelton.

Cost factors	One-half acre field	One-acre field	Nine-acre field
Fitting land	$ 6.20	$ 10.40	$ 10.00 per a.
Planting & cost of seed		61.60	66.50 per a.
Seed at $2.90 and hauling seed at $0.88	15.38		
Cutting seed	1.64		
Labor in planting	3.48		
Fertilizer & manure		31.00	40.05 per a.
Ten loads manure	10.00		
Hauling manure & spreading by hand	42.68		
Cultivation & hoeing	4.48	13.85	15.00 per a.
Spraying	1.65	8.20	15.00 per a.
Digging & storing	15.62	46.50	20.00 per a.
Marketing	13.23		
Interest on valuation ($400.00 per acre)	12.00		
Overhead expense and taxes	5.80		
Total cost	$132.16	$171.55	$166.55
Yield		150 bu.	170 bu.

production in Wisconsin. At a hearing in Milwaukee, on April 23, 1920, conducted by the Wisconsin Division of Markets, the testimony given by potato growers on the cost of growing potatoes in 1919, showed a wide range of variation. The lowest estimated cost was 56 cents per bushel, while the highest was $2.57 per bushel. In the latter case, the high production cost was due to the yield, which was cut down to 30 bushels per acre as a result of unfavorable crop conditions. The average cost per bushel of those testifying was 78 cents per bushel.

The low cost of production, 56 cents per bushel, was reported by one of the best growers in the state, whose average production per acre was 250 bushels.

It must be evident to the reader, from even the limited amount of data presented, that cost of production is directly correlated with yields; and that yields per acre are largely dependent upon the skill and intelligence of the grower. In certain sections of the country, where the soil and climatic conditions are favorable and the land well supplied with plant food, the skilful grower will inevitably produce a crop of potatoes at a much lower cost per bushel than will some other grower, equally skilful, who attempts to grow potatoes under less favorable soil and climatic conditions. I am firmly convinced that the only solution of the present high cost of production is that of increasing the yield per acre through the use of high grade seed, and the adoption of up-to-date methods of culture, harvesting, and marketing of the crop. When the average production of some of our largest producing states is raised to 150 or 200 bushels per acre, instead of from 85 to 95 as at present, the question of cost per bushel and net returns per acre will have been satisfactorily solved.

QUESTIONS ON THE TEXT

1. Upon what two factors is the successful conduct of any manufacturing enterprise largely dependent?
2. Why does it require as high a degree of intelligence to produce a good crop of potatoes, as in the manufacture of potato machinery?
3. Why does the mere statement that it costs $175.00 to grow an acre of potatoes mean so little?
4. How may we arrive at a proper and fair basis in the production of potatoes?
5. What are the cost factors involved?
6. What items should be charged against the crop for labor?
7. What should be included under materials?
8. On what should interest charges against the crop be based?
9. What are the legitimate insurance charges?
10. On what should a tax charge be levied?
11. How should depreciation be estimated?
12. Discuss overhead charges.
13. What is meant by risk?
14. What charges should be included under miscellaneous items?
15. Why is it impossible to give a set of cost data which could be regarded as standard for the whole country?
16. Explain App's method of arriving at the cost of producing potatoes on some New Jersey farms.
17. According to App's data, what did it cost these growers to produce a bushel of potatoes.

18. What was the total production cost per acre, and the net income from same?
19. What was the average price received per barrel by these growers?
20. What was the average labor income from these farms?
21. What variations do the data from different portions of New York State show?
22. How do Steuben County data compare with those of Nassau County?
23. What is the chief item of difference?
24. Compare the per bushel cost in Steuben and Nassau Counties and explain reason why Nassau growers obtained a larger net income per acre.
25. Give reasons for better showing made by Clinton and Franklin County growers than by those from other sections.
26. What correlation is shown by the data between production cost per bushel and net profit per acre?
27. What is the real determining factor governing net profit in the data presented?
28. What would have happened to the Nassau County growers had they been obliged to sell their crop for the same price as the Steuben County growers?
29. What is the chief lesson to be derived from Pelton's data?
30. What did the Milwaukee hearing on potato production costs in Wisconsin in 1920 reveal? Give variation in cost of producing a bushel of potatoes.
31. What were the explanations given for the high and low production costs?
32. How can we reduce production costs? What is the urgent necessity for doing so?

QUESTIONS SUGGESTED BY THE TEXT

1. To what extent do local growers make use of the business principles given here?
2. What are the local costs per acre and per bushel?
3. From the list of cost factors, make a set of questions that will help determine the cost per bushel on a given farm.
4. Use this questionary on a few of the leading farms.
5. How do these results compare with those given in this chapter?
6. What difficulties are encountered in filling such a questionary?

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CHAPTER XII

HARVESTING, PICKING AND HANDLING—GRADING, SHIPPING AND MARKETING THE POTATO CROP

Harvesting the Crop.—The harvesting of the potato crop is generally regarded as the most laborious process involved in the growing of this most important vegetable. In some sections of the North, as in the northern part of Maine, Michigan, Wisconsin and Minnesota it is also regarded as the most critical operation of the season, on account of the ever-present possibility of unfavorable weather, chiefly rains, delaying the work and thereby exposing the crop to injury from freezing. The factors to be considered in harvesting the potato crop are: (1) Date of harvesting; (2) implements used; (3) containers used; and (4) method of handling the crop.

Date of Harvesting.—The date of harvesting the potato crop is very largely governed by the character of the crop and the locality in which it is grown. By the character of the crop is meant whether it is grown as an early or a late crop. The date is also further determined by the market demand and the selling price. For example, the early truck crop of the South is very rarely allowed to reach full maturity before being harvested. Harvesting operations usually begin as soon as the yield of marketable potatoes justifies the grower in sacrificing yield for the sake of securing the higher price which usually prevails in the early part of the season. On the other hand, the late or main crop of the North is usually allowed to remain in the ground until the plants are fully ripe or until the early frosts have killed them. In short crop seasons, high prices and an active demand induce many a grower of late potatoes to harvest his crop before it is ripe, in order to take advantage of the prevailing prices. It is thus seen that the date of harvesting does not necessarily represent any fixed stage of maturity of the potato crop. As the southern crop is only allowed to reach maturity, before being harvested, in seasons when the price is considered too low to justify digging and marketing it, we may consider that the usual time of harvesting is when the crop is still immature, but of sufficient size to give a fair yield. In the North, on the other hand, the customary practice is to allow the crop to mature—weather conditions, of course, permitting.

Harvesting Implements and Their Operation.—The implements that are used in harvesting the potato crop may be conveniently classified into two groups: (1) hand implements; (2) horse implements.

Hand Implements.—The hand implements are the ordinary hoe; the pronged or tined hoe (Figs. 70 and 71), spading fork,

Fig. 70.—Harvesting potatoes in the old fashioned way. Hill selection is possible when the crop is dug in this manner.

six tined manure fork and a specially constructed hand digger, with a lever attachment in the rear which enables the operator to pry instead of lift the plant, with its tubers, out of the soil. Harvesting a potato crop with any of these implements is a slow and laborious process, and is only practised where relatively small areas are grown for family use. In the earlier days, before the development and perfection of the horse-drawn digger, men became expert in the use of hand operated implements, and rather exceptional individual performances are on record. Expert hand diggers have been known to dig and pick up 100 or more bushels of potatoes in a day.

With any of these implements, a careful digger can harvest the crop with a minimum amount of injury to the tubers; but let the same instruments be used by a careless workman, and from 50 to 75 per cent of the crop will be injured in removing the tubers from the soil.

Horse Implements and Their Use.—Many varieties of horse drawn implements are now being used in the harvesting of the potato crop. These may be roughly divided into two classes: the non-elevator, and the elevator implements.

Non-elevator Implements.—The first class may be divided into four groups: (1) the ordinary one or two-horse plow; (2)

Fig. 71.—Harvesting potatoes by hand in the tule lands near Stockton, Calif. The potatoes are gathered as dug.

especially constructed diggers with rigid finger-like attachment to separate the tubers from the soil (Fig. 72); (3) similar implements to class 2 except that the finger-like attachment is agitated by a sprocket wheel, thus insuring a better separation of the tubers from the soil (Fig. 73); and (4) the light drawn potato digger, with revolving fork-like attachment in the rear, which throws the potatoes and soil raised by the shovel point to one side. The separation of the tubers from the soil is supposed to be accomplished by this operation.

The Ordinary Plow.—While the one or two-horse plow cannot in any sense be regarded as a potato digger, it has been and still is a rather commonly employed implement in harvesting the early or truck crop of potatoes in the South. The potato rows are plowed out by turning as light a furrow as possible without cutting the lower tubers with the plow point (Fig. 74). After the potato plants are plowed out in this manner, the furrow is gone over by the laborers, usually women and children, for the purpose of removing the tubers from the soil and throwing them into small piles (Fig. 75). This operation is commonly known as grabbling potatoes. Usually the tubers from two rows are thrown together. They are then gathered into containers. This method of harvesting the southern crop was quite generally practised throughout the South prior to the World War. The scarcity and high price of labor, as a result of war conditions, virtually forced the southern grower to adopt the more modern and labor saving elevator type digger. It is questionable whether, with the return of cheaper labor, the former methods of harvesting the crop will be resumed. In many sections modern machinery will permanently supplant the plow, and thus eliminate the slow and costly practice of grabbling the potatoes from the soil.

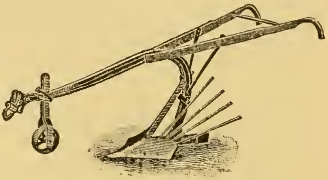

Fig. 72.—The Eclipse digger with rigid rods to separate the tubers from the soil.

Potato Diggers 2 and 3.—The types of diggers given as classes 2 and 3 above are of plow-like construction except that the mold-board is replaced by finger-like iron rods arranged like an arc of a circle (Fig. 76). The plow point passes directly beneath the plants, and the soil and plants are forced up over the iron rods. The separation of the tubers is supposed to take place by the soil dropping through the fingers as it is forced back. Class 2 implements with the rigid rods do not separate the tubers from the soil as completely and satisfactorily as do those in class 3. Either implement gives better results in a sandy or light loamy soil than in a heavy one, or on a dry rather than a wet soil. They are a desirable substitute for the ordinary plow and, where small acreages are involved or where the soil is full of small stones, may prove more satisfactory than the more expensive elevator type of digger. Implements of this type, when intelligently operated, will cause but little injury to the tubers as compared with the elevator type.

Potato Digger No. 4.—Diggers of this class are not generally used in the United States. That they are used is evident from the fact that they are manufactured. It is not possible here to discuss their merits or demerits. From the construction and general appearance of the machine, (Fig. 77), one can readily believe that, in a loose soil, it could be operated very successfully. It is evident that the tractive power required to operate such a machine should be less than for the heavier elevator type of digger.

Elevator Potato Diggers.—The elevator type of potato digger is, with but few exceptions, quite generally used in the strictly commercial production centres of the North and West, and is gradually coming into general use in the South. There are many makes of diggers, and each manufacturer claims special features of superiority for his particular machine. It is doubtful if one would be justified in naming any particular make of machine as being superior to all others. There are, however, certain outstanding features of difference in construction which may be noted. According to these differences, elevator diggers may be separated into five classes as follows: (1) Those with forward truck attached to the pole (Fig. 78); (2) those with truck attached to the iron frame of the machine (Fig. 79); (3) those with conveyor, and rack head (Fig. 78); (4) those with a second conveyor in place of rack head (Fig. 81); and (5) those having a picker attachment (Fig. 78). There are doubtless many other features of difference which, while not so apparent, might well be considered as constituting a separate class or type.

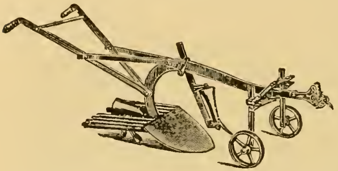

Fig. 73.—A bar type of digger with sprocket wheel behind to shake the soil from the tubers. The two lead wheels straddle the row.

Operation of the Elevator Digger.—The tractive power required to operate the elevator type of digger varies with the character of the soil and the method of culture practised. In Aroostook County, Maine, where ridging is practised and the soil for the most part is light and porous, it is seldom that one sees more than two horses being used to operate the digger (Fig. 80). In the Middle West, where level culture is practised, three and four horses are required (Fig. 82). The same number of horses are also necessary in the irrigated sections of the West.

To leave the impression that the elevator digger can only be operated by horses would be misleading, because the tractor is now being quite freely used in some sections to haul the digger, and its further use for this purpose is almost certain to increase. The caterpillar type of tractor seems to be well adapted to this purpose, (Fig. 83), though possibly it would hardly be justifiable to claim that it was actually superior to other makes. Within the past few years, elevator digger manufacturers have added a gasoline engine to the equipment of some of their diggers (Figs. 78 and 79). The

FIG. 74.—Plowing out the potato crop with a turning plow. A common method of harvesting potatoes in the South.

engine is mounted over the conveyor and is designed to operate the conveyor, kicker and rear rack vine and tuber separator. This relieves the horses of the tractive power required to operate these several parts, which, in the absence of the gasoline engine, are operated by being geared to the wheels of the digger. With the gasoline engine functioning properly, the horses have only to exert the necessary power to haul the machine, and at the same time force its shovel point beneath the potato tubers and push soil and tubers on the conveyor.

The successful operation of a potato digger involves several points, the careful observance of which will guarantee the removal of the crop with a minimum amount of mechanically injured tubers. The operator has much to do with the efficiency of any make of machine as regards the per cent of injured tubers and the thoroughness of the work in general. This may be illustrated by mention of the following point. The shovel point of the digger should be so adjusted as to go deep enough to avoid cutting the tubers. It is almost equally important, on the other hand, to not go any deeper than is necessary, so as to avoid increasing the draught, as well as the overtaxing of the conveyor, especially if

FIG. 75.—Grabbling out the covered tubers after the row has been plowed out with a walking plow. A laborious and rather costly operation.

the soil is heavy or a little wet. The clogging of the conveyor is a source of annoyance to the operator and a direct loss of time to the owner. In light soils and where the vines have thoroughly ripened, it is sometimes a good plan to go somewhat deeper than is necessary in order to prevent undue injury to the tubers by the soil sifting through the conveyor chain too quickly, thus permitting the tubers to travel over a large portion of the bare conveyor. By attention to this detail, and the removal of a portion or all of the conveyor agitators, much surface injury may be avoided. Another prolific source of injury is that of driving the machine too fast. This often causes an unnecessary amount of agitation. The author has personally observed four diggers at work in a potato field on sandy soil, where the horses were frequently allowed to break into a slow trot. At such times, the potato tubers would frequently bound from the conveyor to a height of eighteen inches or more.

In heavy soils and where the vines are heavy, fast driving seems to lessen the amount of clogging; consequently, the operator is often

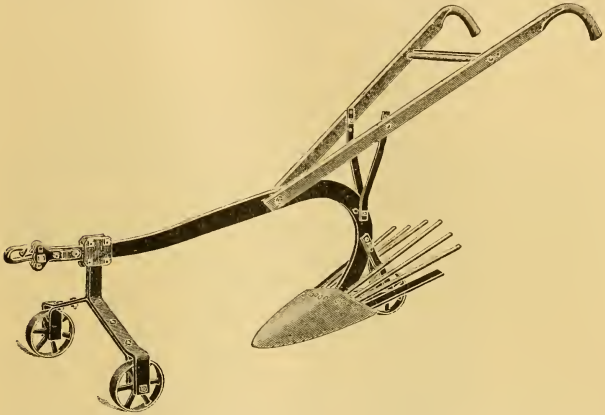

FIG. 76.—Digger with typical shovel point and arc-formed tines, and two guide wheels in front.

tempted to drive faster than is necessary. When the digger is equipped with a gasoline engine it is possible to drive slower; since the speed at which the conveyor moves can be regulated at will by the operator. Mechanical injury of the tubers may be still further lessened by lowering the rear rack or conveyor, as the case may be, to a point where the drop of the tubers from the digger to the ground will be so slight as to cause little, if any, injury (Fig. 84).

When properly adjusted, the elevator type of digger should deliver the vines at one side of the row and the tubers in the centre. Some makes of machines do this more effectively than others, chiefly on account of a slightly different arrangement and curve of the vine and tuber rear rack rods. A machine operated at an even rate of speed will always do more effective work than when jerky or varying speed movements are permitted.

Under favorable conditions, the elevator digger will dig from three to four acres per day.

Picking and Handling the Tubers.—In different sections of

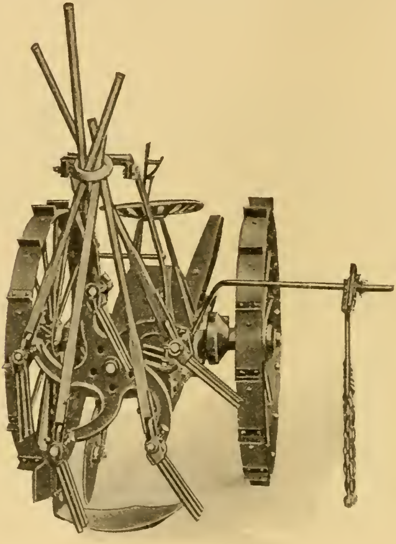

Fig. 77.—A light draught potato digger with revolving fork-like attachment in the rear, which throws the potatoes and soil to one side of the row.

the country, varying practices prevail in regard to the picking and handling of the newly dug tubers. The early crop in the South, for example, is generally graded as it is picked, and is at once put into the containers in which it is to be shipped to market. When the weather is hot, the potatoes should be gathered as quickly as possible after they are dug, as they are easily injured by the hot sun. In very warm weather, the more careful and experienced southern growers aim to dig in the late afternoon, leaving many lying on the ground over night to be gathered early in the morning when they are well cooled off. It is always advisable to haul the crop out of the field as soon as convenient after it has been sacked or barrelled.

The southern grower uses baskets, buckets, hampers and crates in picking up potatoes (Figs. 90 and 91).

In Maine, the potatoes are usually gathered into splint baskets with a strong wooden bale (Fig. 84). The tubers are transferred from the basket to the barrel and in general the transfer is not made

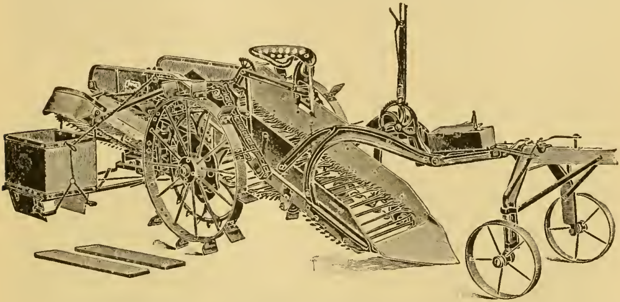

Fig. 78.—Combined potato digger and picker.

in as gentle a manner as could be desired. The quick dumping of a basket of potatoes into an empty barrel inevitably injures the surface of many of the tubers. Much injury could be avoided by tipping the barrel, when emptying the first two or three baskets; or by lowering the basket into the barrel before emptying it. They are hauled in the unheaded barrel from the field to the shipping station or the home storage house as the case may be (Fig. 84).

In New Jersey, some of the early crop is gathered into five-eighth bushel splint baskets (Fig. 85), in which they are hauled direct to market, or to the sizer if they are to be graded and shipped in sacks. The American Giant Crop of Monmouth County, New Jersey, is gathered into baskets from whence it is emptied into sacks. This crop, like the early Irish Cobbler crop, is generally hauled direct from the field to the shipping station. The grading is done by the pickers as they gather the crop, or the tubers are run over a sizer in the field or loading station.

In Western New York, and in some sections of the Middle West, the potato crop is gathered into wooden boxes or crates holding a bushel (Fig. 86), in which they are hauled from the field to the storage house, cellar, or shipping station. In the West, and in some sections of the South, a large part of the crop is gathered in wire baskets by the pickers, and transferred to two bushel sacks if the crop is to be stored. If it is being marketed as dug it is

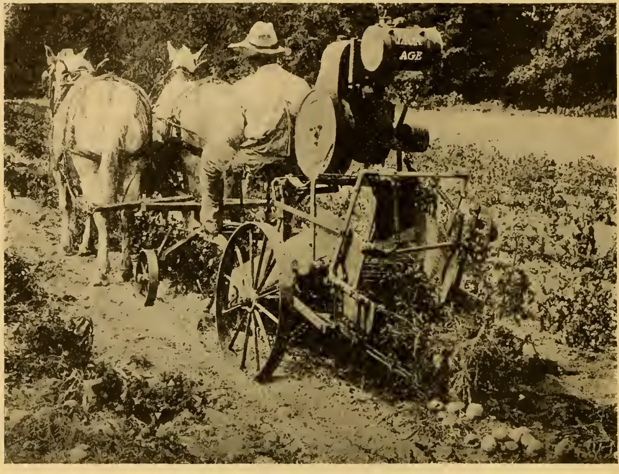

Fig. 79.—By the aid of the gasoline engine to operate the conveyor belt, vine kicker and vine and tuber separating rod racks, the traction necessary to haul the digger is reduced to a point where two horses can easily handle it. Note low position of tuber rod rack. When lowered in this manner the drop is so slight that it does not injure the tubers. Courtesy of Bateman Mfg. Co.

usually graded in the field (Fig. 85). Careful growers cover the inside of the wire basket with burlap to prevent tuber injury. When stored on the farm, the pickers empty three half-bushel baskets into each sack. The sacks are hauled to the storage house without being tied, and are emptied directly into the storage bin.

In the tule lands of the Stockton, California district, where it is claimed the digger cannot be successfully operated, the crop is dug by hand. Each workman has his own basket and gathers the tubers as he digs them.

Cost of Picking Potatoes.—The wages paid to potato pickers have advanced so rapidly during the past few years that it is difficult to give accurate cost data on the gathering of the potato crop. In Aroostook County, Maine, prior to 1914, it was customary for the grower to pay pickers from 6 to 8 cents a barrel and board. Day help received from $2.00 to $2.50 per day and board in the early part of the digging season, and from $2.50 to $3.00 toward its close. The prices paid in the same locality in 1920 were from 15 to 16 cents a barrel and board, or 17 to 18 cents without board. Day labor started at $5.00 per day and board, and wound up at $6.00 to $7.00 per day. Expert Maine potato pickers, when the yield is good, have been known to pick as high as 125 barrels in a day. A few men, under favorable conditions, will average 100 or more barrels. The average picker will pick about 60 barrels per day.

Fig. 80.—This elevator digger is being successfully operated by two horses without the aid of a gasoline engine. In this picture we have a good view of the vine and tuber separating rod rack.

In the Red River Valley, pre-war prices were about four cents a bushel.

In the Norfolk, Virginia, section, 10 cents a barrel was considered a good price prior to 1914, but in 1920, 20 cents was demanded for the same service.

Grading.—Potato grading has received more attention during the past three or four years (1917-21) than at any previous time in the history of the potato industry of this country. The primary cause of this increased interest was a ruling, made by the United States Food Administration during the season of 1917-18, compelling the large handlers of potatoes to grade them according to certain prescribed standards, formulated by the Bureau of Markets of the United States Department of Agriculture. Without attempting to go into the details involved in this first effort on the part of the government to enforce the grading of potatoes, it may suffice to say that the objections to the potato grade rules on the part of the growers have been largely overcome; and in the section where the bitterest opposition to grading developed, we now find the growers heartily in favor of it. While the recognition of the merits of a uniform and standard grade of potatoes

Fig. 81.—A potato digger with rear conveyor belt. Such a machine does not separate the vines from the tubers. Greeley, Col.

was rather slow, it is believed that the majority of the growers are now heartily in favor of the movement.

Grades.—The most recent grade requirements, promulgated by Truax[4] of the Bureau of Markets, provide for three grades, *viz.*: U. S. Grade Fancy, U. S. Grade No. 1, and U. S. Grade No. 2. The requirements of these grades are as follows:

"**U. S. Grade Fancy.**—This grade shall consist of sound potatoes of one variety which are mature, bright, smooth, well shaped, free from dirt or other foreign matter, frost, injury, sunburn, second growth, growth cracks, cuts, scab, blight, soft rot, dry rot, and damage caused by disease, insects, or by mechanical or other means. The range in size shall be stated in terms of minumum and maximum diameter or weight following the grade name,* but in no case shall the diameter be less than two inches.

"In order to allow for variations incident to commercial grading and handling, five per centum by weight of any lot may vary from the range in size stated, and, in addition, three per centum by weight of any such lot may be below the remaining requirements of this grade; but not more than one-third of such three per centum, that is to say, not more than

FIG. 82.—A four-mule team operates one digger while two horses and a gasoline engine operate the other.

one per centum by weight of the entire lot, may have the flesh injured by soft rot.

"**U. S. Grade No. 1.**—This grade shall consist of sound potatoes of similar varietal characteristics which are practically free from dirt or other foreign matter, frost injury, sunburn, second growth, growth cracks, cuts, scab, blight, soft rot, dry rot, and damage caused by disease, insects, or mechanical or other means.

"The diameter of the potatoes of the round varieties shall not be less than one and seven-eighth inches, and of potatoes of long varieties one and three-fourth inches.

"In order to allow for variations incident to commercial grading and handling, five per centum by weight of any lot may be under the prescribed

* Such statements as the following will be considered as meeting this requirement: "U. S. Grade Fancy, 2 to 3 inches;" "U. S. Grade Fancy, 10 to 16 oz.;" "U. S. Grade Fancy, 2 inches and larger;" "U. S. Grade Fancy, 10 oz. and larger."

size, and, in addition, six per centum by weight of any such lot may be below the remaining requirements of this grade; but not more than one-third of such six per centum, that is to say, not more than two per centum by weight of the entire lot, may have the flesh injured by soft rot.

"**U. S. Grade No. 2.**—This grade shall consist of potatoes of similar varietal characteristics, which are practically free from frost injury and soft rot, and which are free from serious damage caused by sunburn, cuts, scab, blight, dry rot, or other disease, insects, or mechanical or other means.

"The diameter of potatoes of this grade shall not be less than one and one-half inches.

Fig. 83.—The potato digger can be successfully operated by a tractor. Presque Isle, Me.

"In order to allow for variations incident to commercial grading and handling, five per centum by weight of any lot may be under the prescribed size, and, in addition, six per centum by weight of any such lot may be below the remaining requirements of this grade; but not more than one-third of such six per centum, that is to say, not more than two per centum by weight of the entire lot, may have the flesh injured by soft rot.

"**Definition of Grade Terms.**—As used in these grades:

"'Mature' means that the outer skin (*epidermis*) does not loosen or 'feather' readily during the ordinary methods of handling.

"'Bright' means free from dirt or other foreign matter, damage or discoloration from any cause, to an extent such that the outer skin (*epidermis*) has the attractive color normal for the variety.

"'Smooth' means free from second-growth, growth cracks, and other abnormally rough surfaces.

"'Well shaped' means the normal, typical shape for the variety in the district where grown, and free from pointed, dumb-bell shaped, excessively elongated, and other ill-formed potatoes.

"'Free' means that neither the appearance nor the physical structure has been appreciably damaged by the causes mentioned.

FIG. 84.—The rear rack head in this digger is lowered to a point where the tubers have almost no drop. The picture shows an everyday scene on almost every Aroostook County, Me., farm during September and the early part of October.

"'Diameter' means the greatest dimension at right angles to the longitudinal axis.

"'Soft rot' means a soft mushy condition of the tissues from whatever cause.

"'Practically free' means that the appearance shall not be injured to an extent readily apparent upon casual examination of the lot, and that any damage from the causes mentioned can be removed by the ordinary process of paring without appreciable increase in waste over that which would

FIG. 85.—Grading potatoes with a belt grader Bridgeton, N. J. Potatoes gathered into $\frac{5}{8}$ bushel splint baskets, in which they are hauled to the sizer. Courtesy of Minch Bros. Bridgeton, N. J.

occur if the potato were perfect. Loss of outer skin (*epidermis*) only shall not be considered as an injury to the appearance.

"'Free from serious damage' means that any damage from the causes mentioned can be removed by the ordinary processes of paring without increase in waste of more than ten per centum by weight over that which would occur if the potato were perfect."

Potato Grading and Mechanical Sizers.—The importance of properly grading potatoes before shipping them to market cannot be too strongly emphasized. The place to grade them is on the farm, or at shipping point, if proper facilities are not available on the farm. The old custom of shipping ungraded stock is being gradually abandoned, as the grower comes to realize the folly of expecting the large commission merchant, or the distributor at terminal receiving points to perform this service at his own expense. The realization that he pays for this service, and that such service is infinitely more expensive in the city than on the farm or at shipping point, and that, in addition, he pays the freight on the stock that the distributor culls out is rapidly converting the grower to the idea of home grading. Well graded stock, put up in attrac-

FIG. 86.—A potato harvesting scene on the farm of T. E. Martin, West Rush, N. Y. In this section of New York State it is a common practice to gather the potatoes in bushel boxes. By courtesy of T. E. Martin.

tive containers, will always sell at a premium over ordinary stock, and will pay many times over for the slight cost involved in grading the stock. Ungraded stock usually sells on the basis of the poorest material in it, rather than on its average quality.

Method of Grading.—While it is possible to hand-grade potatoes, it is not so economical of time as is desirable where large quantities of potatoes have to be handled. The use of the mechanical sizer greatly facilitates the work of grading.

Mechanical Sizers.—Although there are many makes of mechanical sizers, or, as they are designated by the manufacturers, potato graders, on the market at the present time, they can all be broadly separated into three classes, *viz.,* those with sizing belt conveyor, operated by a crank turned by hand, or by pulley connected with a gasoline engine or electric motor (Figs. 85 and 87); those in which the screen is suspended between the wooden or steel frame of the sizing machine (Fig. 89); and small hand screens resting on a stand (Figs. 90 and 91).

The sizing machine, when properly operated, removes all the undersized potatoes, as well as the loose dirt collected with the tubers in picking them up. The first type of machine is usually

FIG. 87.—Sizing potatoes with a large power-driven sizer having a capacity of over 100 barrels per hour. The potatoes are hauled from the field to the sizer in slat crates. On the G. W. Waller farm, Hastings, Fla.

constructed with two belts, the one with the smaller sized meshes operating within the other. This gives two grades of potatoes, No. 1 and No. 2, and the culls. Some of the larger machines, constructed chiefly for use on the early crop in the South, are provided with three belts, which give three sizes, 1's, 2's and 3's.

The second type of sizer seems to be almost wholly a western product, where it is used almost to the entire exclusion of the first type. This type of sizer is operated by the workman doing the grading by rocking or shuffling it back and forth. The only reason that can be suggested for this apparent regional preference is that the belt conveyor type is of later origin, and has not as yet generally invaded western territory. In our opinion, the belt conveyor type of sizer possesses some points of advantage over the western type, in that, if properly operated, it should not skin and bruise the tubers as much as the other. The jolting back and forth of the tubers on the sizing screen, as the potatoes roll forward, is much more likely to skin and bruise them than will its even movement over the belt conveyor. A simpler type of sizer is quite generally used in Texas and adjacent states. It consists in some localities of what might be regarded as an ordinary old-

FIG. 88.—A handy labor-saving device for removing the barrels of sized potatoes from the sizer. Note small trucks operating on wooden tracks. By having two tracks with a truck on each there is no interruption in the operation of the sizer. On the G. W. Waller farm, Hastings, Fla.

time circular hand screen, the bottom of which is covered by a heavy wire screen with one and three-fourth inch meshes. This screen is placed on a specially constructed wooden stand with bag attachments (Fig. 90). The potatoes are dumped into the screen as gathered and briskly shuffled back and forth until all the dirt and small potatoes have been shaken through, after which the remaining tubers are dumped through an opening in the stand into a sack attached beneath it. In the Brownsville district, in southern Texas, an oblong hand screen is used (Fig. 91). While this is a more or less primitive method, as compared with the mechanical sizer, it serves the purpose and is so cheap that the grower can own a sufficient number to distribute along the entire length of any of his fields, thus having them convenient to the pickers in any portion of the field.

In Maine, the growers, as a general rule, use what is known as a rack or sorting table (Fig. 92) when grading potatoes. This table is usually of home construction, and is simply used as a

Fig. 89.—The western type of potato sizer mounted on sled runners to permit of hauling it with a horse or horses.

convenient method of hand sorting and sacking or barrelling the stock. All unmerchantable stock is supposed to be removed as the potatoes roll down into the sack or barrel. When the grading or "racking," as it is usually called, is done, after the potatoes are stored they are generally shovelled onto the rack, but when the stock is racked from barrelled material a board, cut to fit the lower opening of the sorting table, is used to prevent the potatoes from rolling out when the barrel is emptied at the upper end. Skilled workmen can sort and grade potatoes quite rapidly by the aid of such a sorting table, and, where reasonable intelligence and care

are exercised, material will conform to United States grade requirements. The open slat bottom of the sorting table serves to dispose of all refuse and the very small potatoes that may be in the stock. The sorting table is never used in the field.

Grading for a Fancy Trade.—Here and there may be found the beginnings of an attempt, usually on the part of dealers, to develop a select market for a uniform sized tuber put up in a special package. As yet, the bushel box seems to be the favorite

Fig. 90.—Type of hand-sizing screen and stand used in the Eagle Lake district in Texas.

container. Smooth uninjured tubers are selected and wrapped in a light wrapping paper and carefully packed in containers. In one instance that has attracted attention, a light brown wrapping paper was used and each wrapper was sealed with sealing wax. The seal used gave the name of the firm putting them up (Fig. 93). They were packed in a 50 pound container and sold for about $3.00 per box when ordinary stock was selling at about $1.00 per hundredweight. The selected tubers averaged about nine ounces in weight.

A few years ago, a New York firm was observed that had developed quite a volume of business in supplying high class hotels and restaurants with special sizes of potatoes for baking, boiling, and frying. The bakers averaged nine to ten ounces and each tuber was wrapped. The price received was around four cents per tuber.

It has long been an opinion that the development of a special trade for fancy graded potatoes was a perfectly feasible proposition for those in a position to furnish a continuous supply. The idea is that there is a necessity for the marketing of well graded potatoes in small packages that the retailer can sell direct to the consumer without breaking the package. Potato tubers can be sepa-

FIG. 91.—Type of hand screen used in the Brownsville district in Texas.

rated without much trouble into sizes, running from 3 to 4, 4 to 6, 6 to 8, 8 to 10, 10 to 12, etc., ounces and put in heavy paper carton packages of 10, 15, and 20 or more pounds in weight (Fig. 94). Heavy manila paper bags may be substituted for the carton boxes. The housewife who desired boiling potatoes could make use of either of the first two sizes. If bakers were desired, the 6 to 8, or 8 to 10 ounce tuber sizes would be found to meet her requirements. The larger sizes would be found more economical for frying, potato chips, etc. The advantage of having potatoes of a certain size is that they will all cook in about the same time, and with a little experience, the time required to cook a given size can be quite accurately determined. These are some of the advantages from the housewife's standpoint; but a number of others might be given, such as the advantage and convenience to the retailer of handling potatoes in unbroken packages; the elimination of waste; the guarantee that each package contains sound tubers of a given size; and finally, the quality of the potato does not deteriorate by being exposed to light, as it ordinarily does when handled in bulk by the retailer.

The successful development of such an enterprise is largely dependent upon the willingness of the consumer to pay a sufficient premium over ordinary stock to make it profitable to grade the potatoes and put them up in the manner described. Service of this sort cannot be rendered unless it is amply reimbursed. It is believed that the well-to-do consumer is willing to pay the price, provided he gets the quality demanded. With the question of remuneration settled, the further and continued success of the enterprise is wholly dependent upon the grower or the dealer actually engaged in the grading and putting up of the material. As long as he performs this task in an honest manner, and is able to furnish the retailer with a steady supply throughout the season, he may expect a constantly increasing demand for his product.

Fig. 92.—Sorting table or rack used by Maine growers.

Large establishments, such as mail order grocers and others, have expressed a willingness to handle potatoes put up in small packages, provided they could be assured of a steady supply.

Injury to Tubers in Picking and Grading.—Some mention has been previously made as to injury to the tubers occasioned by the rocking and belt conveyor types of graders, but no special emphasis was laid upon the necessity of exercising the utmost care in this matter. In the case of the early crop of the South, which is usually harvested when immature, it is very necessary to handle it with as much care as possible to avoid skinning and bruising the tubers. It is quite important to reduce the handling of the potatoes to a minimum, and, for this reason, many of the best growers still prefer to have the pickers grade the stock into No. 1's and 2's as it is gathered. In this way the potatoes receive the minimum of handling, as they are transferred to barrels or sacks directly from the receptacles in which they are gathered. In the Hastings district in Florida, it is quite a common practice to use

FIG. 93.—A box of select baking potatoes wrapped in a light but tough brown wrapping paper with free end fastened to wrapper with sealing wax stamped with the firm's name.

collapsible slat crates in picking up the potatoes. The filled crates are hauled to the grader where they are sized, graded and barrelled (Fig. 87). Where the sizing machine follows the pickers in the field, there is also a minimum amount of handling. Much injury can be avoided by the exercise of care in emptying the basket or crate of potatoes on the grader, and in the reduction of all unnecessary height of drop from the grader into the container,

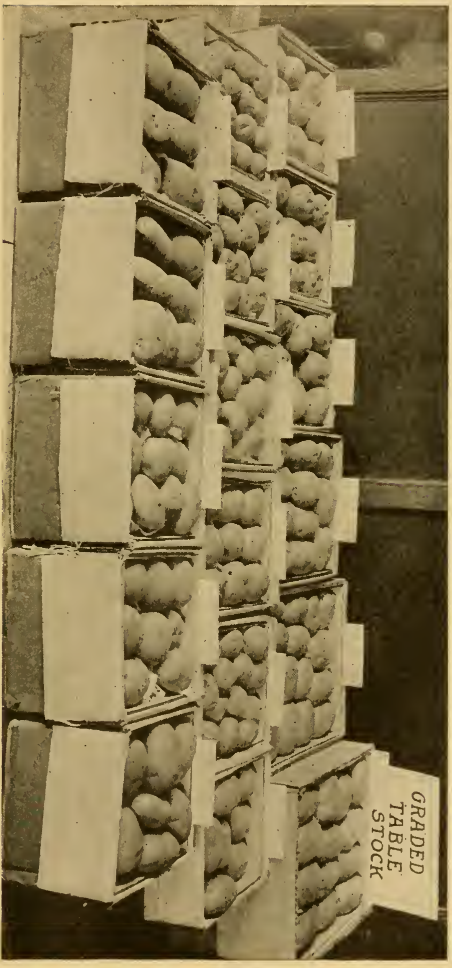

FIG. 94.—An exhibit of well-graded potatoes packed in pasteboard carton packages holding 10, 15, and 20 pounds. The tubers in these various cartons are sized so that in no package is there a greater variation in weight of individual tubers of more than two ounces.

in which they are to be shipped to market. Mechanical injuries may be still further reduced where machine sizers are used, especially when they are operated by gasoline engine or electric motor, by operating the conveyor belt at a moderate rate of speed. When the tubers, through a too rapid movement of the belt conveyor, are forcibly discharged from the spouts of the sizer and allowed to drop to the bottom of a barrel, it is inevitable that many more bruises and cuts will result from this method of handling than when a moderate speed is allowed, and a piece of canvas or gunny sack is used to break the fall of the tuber into the barrel. The application of common-sense methods of handling the potato crop will do much toward lessening the bruising and cutting of the tubers, and will materially improve their appearance on arrival at destination point.

FIG. 95.—Hauling empty barrels to potato field near Onley, Va. Note size of load, also that they are all stave barrels. Few if any splint barrels are used in the Eastern Shore district.

Shipping and Marketing.—The shipping and marketing of potatoes in a successful and businesslike manner calls for an entirely different kind of experience or ability from that possessed by the average grower. Some of the best potato growers are a sad failure when it comes to the business end of shipping and salesmanship. It should be borne in mind, too, that when distant markets have to be sought in the disposal of the crop it is often impossible or impracticable for the grower to dispose of his own crop, unless he is fortunate enough to have selected a good commission house to which he can consign it. There is still another factor involved in the marketing of an individual's crop, especially for the southern truck grower, who must always ship to a distant market, and that is that, unless he is a large grower, he is unable to load a car inside of twenty-four hours as it is usually desirable to do.

Containers.—The first consideration in the shipping and marketing of the crop is the container in which it is to be packed for shipment. As the appearance of the package or container has much to do with the successful marketing of the crop it is important that the potatoes be put up in clean and attractive containers. The types of containers used the country over in marketing potatoes named in the order of their widest use are the burlap sack of 100, 120, 150 and 165 pounds capacity; stave and splint barrels, with burlap cover (Figs. 95 to 100); the double-headed stave barrel; the hamper of varying capacity usually 50 pounds; and the five-eighth bushel peach basket (Fig. 101). Large quantities of northern grown stock, especially in the early autumn, are marketed in bulk.

Fig. 96.—The Beaufort S. C. type of splint barrel with inner set of hoops which impart a considerable degree of rigidity to the barrel.

The double-headed barrel is, so far as the writer is informed, used only in Florida, and most largely in the Hastings district. When well ventilated double-headed barrels are properly filled with bright, well-graded stock, headed and neatly stencilled, they present the most attractive appearance of any potato container used, (Figs. 87 and 88); and, when opened, the potatoes show the least injury from handling.

Two reasons might be advanced for the double-headed barrel not being more generally used by southern truck growers, the first being the cost, and the second, the additional labor involved in heading the barrels. Prior to the war, the double-headed barrel cost the grower in the neighborhood of 36 cents. In 1918 they cost from 70 to 85 cents, and were not obtainable in sufficient quantity to meet the demands. The pre-war price for splint barrels was 18 cents, and 22 to 24 for the stave barrel.

The use of new burlap sacks with an attractive brand (Fig. 102) gives a more presentable appearance to the package; and the stock usually sells at a sufficient premium above the average to pay the grower handsomely for his additional investment.

One of the crying needs of the day is a standard size of sack. All things considered, the two-bushel or 120-pound sack comes nearest to being the ideal size. It makes a neat and attractive package if properly filled and sewed up, and is not so heavy as to be unwieldy. The 150- and 165-pound sacks are rather heavy to handle, and are more apt to become slack in handling. A properly filled sack should be so firm, when sewed up, as to handle like a stick of cordwood. Such a package will show less tuber injury from handling than will be found in a slack package.

Fig. 97.—A well-graded and well-filled barrel of potatoes ready to be covered with burlap top. This stave barrel is properly ventilated.

A further objection to the use of various sizes of sacks is the confusion it causes in the minds of those who attempt to keep informed on the market quotations. Unless one is familiar with the practices in vogue in different sections, one cannot be certain whether the price given is for a two, two and one-half, or two and three-quarter bushel sack unless it is specifically stated in the report.

The hamper is chiefly used in southern Florida and in southern Texas. Just why the hamper is the container most favored in these sections is rather difficult to answer. The five-sixth bushel hamper and the half-barrel hamper being almost universally used in these sections for the shipment of string beans, green peas and other truck crops, the grower has become accustomed to handling them (Fig. 101). The high price received for the new potatoes is also a very important factor to be considered. The sum of $5.00 or $6.00 for a 50-pound hamper of potatoes does not seem so staggering to the consumer as would $16.50 to $19.80 a barrel.

The five-eighth bushel basket used by some New Jersey growers in marketing their early crop of Irish Cobblers is employed only where nearby markets are to be supplied. (Fig. 85.)

Shipping Potatoes.—The shipping of potatoes to distant markets involves some knowledge of the proper loading of the car or the boat in which the shipment is to be placed. The question of the proper method of loading cars, and the type of car best suited for the purpose has been quite thoroughly discussed by More and Dorland,[3] Bird and Grimes,[1] and Grimes.[2] As a result of these men's studies and the information they have published on the subject, there has been a very considerable decrease in the losses sustained through overheating in late spring and summer shipments, and from frosting during cold periods in the Winter. The proper way to load a car with barrels is to lay the barrels on their sides; begin the first layer of barrels at one end of the car, placing the first against the side of the car, while the next two are placed end to end to each other. The second tier should be staggered with the first (Fig. 103). It is not advisable to place more than three tiers of barrels in the car. Summer or hot weather shipments will not permit of as heavy loading as can be safely practised during the cooler autumn and winter weather.

Fig. 98.—The top hoop is removed from the barrel then the burlap cover is spread over and the hoop pressed down into place over the burlap and well nailed.

The burlap-covered barrel cannot be safely loaded on its side or bilge, as the upper end of the barrel would not sustain the weight of two or more barrels on top of it. Such containers carry best by standing the first tier of barrels on their ends, and placing one tier of barrels on their sides upon the first tier as it is being placed (Fig. 104).

In the summer shipment of potatoes in sacks, it is not advisable to pile them in solid tiers as is done in fall and winter shipments. Grimes recommends (*l.c.* p. 12) "the placing of the first sack on end in one corner of the car with the flat side of the sack leaning against the side of the car." He further says: "Make sure that the bottom of the sack is at least 6 inches from the side of the car. Lean two more sacks against the first. On top of these three sacks place one sack flat, taking care to keep one end at least 10 inches from the side of the car, and the other end well on top of the upright sack nearest the centre line. Another sack should be placed flat on top of this, but with one end tight against the side of the car. The manner in which these two flat sacks are loaded is very important; if they are not correctly and securely placed, the load is practically certain to shift in transit. The same system of placing the sacks is followed on the opposite side of the car. This leaves a narrow centre aisle through the whole length of the car, insuring good ventilation (Fig. 105).

Fig. 99.—A splint barrel being covered. Note light construction of barrel.

In the shipment of sacked potatoes during cool weather an entirely different system of loading is practised. Bird and Grimes[1] suggest laying the sacks lengthwise of the car. The first row of sacks is laid about a foot or so from the end of the car; the second tier should extend a little further back; and the succeeding tiers should be piled likewise (Fig. 106). The car should be similarly loaded from the other end. The object should be to so load the car as to prevent shifting of the load in transit, and, at the same time, make provisions for a free circulation of air around the load. In severe, cold weather, the area in the centre of the car should be left unfilled, thus permitting the use of a heater stove. The car should not be filled clear to the top. It is desirable to leave at least a foot of space, and in large cars 18 inches is preferable.

Hampers do not make satisfactory packages for shipment on account of their frailty. When loaded four tiers high, the lower tier of packages is quite apt to arrive at destination in a badly broken condition. Hampers should be tiered bottom to bottom or top to top as the case may be; by alternating the order of placement of the first tier, it is possible to effect a considerable economy in space, and at the same time increase the solidity of the load. The railroads dislike to carry hamper shipments of potatoes, because they almost invariably have claims presented for injury sustained during transit.

Warm weather shipments should invariably be made in ventilated cars (Fig. 105). The ordinary box car should never be used, unless slat doors are provided.

During the cooler autumn weather, the box car is entirely acceptable as long as there is no likelihood of a low drop in temperature. As soon as severe, freezing weather may be expected, it is unsafe to use a box car except for very short hauls. When shipments are made to distant points during severely cold weather or, when the car in transit is likely to pass through areas where low temperatures prevail, the shipment should be made in refrigerator cars; or in a special type of car provided with a heater, such as the Eastman heater car which, as far as it is available, is used in the movement of potatoes from Maine points. Unfortunately, the supply of refrigerator and heater cars is utterly inadequate for the movement of the potato crop to market during the winter, making it necessary to use the ordinary box car. In order to use box cars the shipper is obliged to go to the expense of lining them with building paper, and constructing wooden false floors, walls and ends (Fig. 106). Full particulars concerning the conversion of a box car into a fairly good substitute for a refrigerator car are given by Bird and Grimes.[1]

Fig. 100.—The hoop in place ready for nailing.

A few favored localities in the South are able to avail themselves of water transportation in moving their crop to market. The most notable example in this respect is that of the Norfolk, Virginia, district where a large proportion of the New York, Boston, Baltimore, and Washington consignments are shipped by boat rather than by rail. (Figs. 107 and 108). The advantage of boat over rail shipment is that the shipper can be absolutely certain of the date of arrival of his consignment when he moves it by boat, while by rail he has no assurance when his potatoes will reach market. New York shipments by boat arrive within 24 hours

Fig. 101.—Hampers filled with new potatoes ready for shipment. San Benito, Tex.

Fig. 102.—In the Ft. Gibson, Okla., district, potatoes are graded and sacked in the field and are hauled in springless wagons to the shipping station. The grower of this stock marks his sacks with a wheel brand. Courtesy of W. H. Olin.

of their departure from Norfolk, and Boston shipments within 36 hours; whereas rail shipments may take several days if not a week or more, depending upon freight congestion in terminal yards.

Marketing.—The successful marketing of potatoes offers many difficulties, particularly in the disposal of the early or truck crop which, on account of its perishable nature and the comparatively short period in which it must be handled, necessitates quick action on the part of the grower or dealer. The development of commercial growing centres is, in part, the outcome of a growing recognition of the advantages derived from having a large output to dispose of at a given shipping point. If the crop volume is large enough, it attracts buyers from all the large northern and middle-

Fig. 103.—Proper way to load double-headed barrels to insure an even distribution of weight. Loaded in this manner, the bulk of weight on upper layers is supported by heads of barrels in lower tier. Courtesy, Bureau of Markets, U. S. Dept. Agr.

western sections of the country, with the result that, when the market demand for new potatoes is brisk, there is keen competition between representatives of different commission firms as to who will secure the largest quantity of the best stock. This competition insures good prices to the grower, and relieves him of the more or less onerous task of attempting to market his own crop. Another advantage is that the crop is given a much wider distribution than it could have possibly received had the growers themselves attempted to dispose of it in distant markets.

In some sections the growers have their own selling organization, and in some cases these have been wonderfully successful. One of the largest and most successful of these marketing organizations is the Eastern Shore of Virginia Produce Exchange located at Onley, Virginia.

The disposal of the new crop becomes difficult and uncertain as to returns when terminal distributing points become glutted through an oversupply and an inactive demand on the part of the retail trade and the consuming public. Under these conditions it often becomes necessary to roll the stock unsold; the usual practice being to consign it to some commission house. Frequently cars are diverted en route, in order to take advantage of a stronger market in some other city than the one to which the car was originally billed.

Fig. 104.—Proper way to load burlap-covered stave barrels. Courtesy of Bureau of Markets, U. S. Dept. Agr.

In the marketing of the late crop of potatoes the grower or dealer has a longer season of operation, and is not dealing with such a perishable product, as the crop is usually mature and the weather cool. The element of risk in shipping late potatoes is that of being frosted while en route to destination, or of a portion of the shipment being injured by overheating when a stove is used in the car.

The method of disposal of the crop is so similar as to require no further discussion.

When Should a Grower Sell?—The proper time at which to dispose of his crop is a question which is often difficult for the grower to decide. Each grower should keep himself informed as to the probable extent of the crop, through the monthly reports of the Bureau of Crop Estimates of the United States Department of Agriculture and all other available sources. Whenever it becomes apparent that a crop in excess of 375 million bushels is going to be harvested, it is a fairly safe assumption that prices will not reach a very high level, unless there is a shortage of other food crops, such as wheat, corn and other products. When no such shortage exists and a large crop is in sight, it is usually advisable to sell the crop as harvested, provided the price at that time

Fig. 105.—Approved method of loading sacks of potatoes for summer shipment. This insures good ventilation. Courtesy of the Bureau of Markets, U. S. Dept. Agr.

affords a reasonable return on the investment involved in its production. There are seasons when it may be advisable to sell the crop from the field at a price which barely covers the actual cost

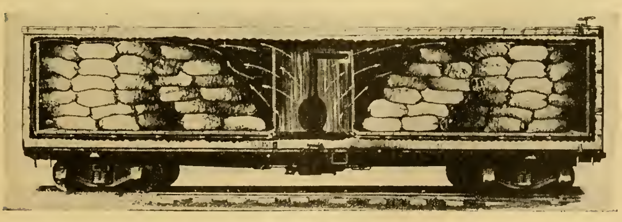

Fig. 106.—Approved method of loading sacked potatoes for winter shipment. Note false floor and ends. This method of loading insures an even and uninterrupted circulation of air. Courtesy of the Bureau of Markets, U. S. Dept. Agr.

of production, and thereby avoid the extra cost of storing and rehandling the crop later in the season, with a fair prospect of not receiving any more for it at that time than when harvested. It is, of course, apparent that if everyone followed this advice it would result in a complete slump in prices. In fact, it would be a physical impossibility for the railroads to move the entire late crop of potatoes during the harvest period; and even if this were possible, there is enough storage to take care of only about one-third of the crop. It thus becomes evident that at least two-thirds of the late crop must be stored on the farm, to await distribution throughout the late fall, winter and early spring months.

FIG. 107.—Hauling the crop to shipping point in the Norfolk district.

On the other hand, when a short crop is apparent it would not be a good plan for every grower to hold on to his whole crop in the expectation of receiving a high price in the spring. The result would be that prices throughout the early part of the winter season would be forced to such an extremely high figure that the consumption of potatoes would be very materially curtailed, with the probability that, when the grower got ready to dispose of his crop, he would find the market overstocked, and the consuming public's taste diverted to other starchy food substitutes. Under such conditions, the price received for the crop might be very much below what it should be as judged by the season's supply. Good stable prices and market conditions can only be expected when there is a steady flow of potatoes to the distributing centres, thus preventing wide price fluctuations, and insuring a maximum consumption.

Every commercial late crop potato grower should aim to provide sufficient storage space on his own farm to enable him to store his whole crop, if need be. When provided with the necessary facilities for taking care of his crop, he is not obliged to dispose of

Fig. 108.—Boats from truck farms awaiting their turn to unload at the Old Dominion docks, Norfolk, Va. An ideal method of conveying the crop to shipping point.

it at harvesting time if the prices being paid are ruinously low. On the other hand, if a satisfactory price is being offered, it is often justifiable to dispose of the whole crop, even though ample provision for storage is at hand. The ideal method of marketing the crop would be for each grower to dispose of a sufficient portion of his crop to take care of the needs of the trade. It goes without saying, of course, that such an ideal will never be reached, as there will always be those who, through lack of storage facilities, are obliged to sell their crop as harvested.

Stabilization of prices for farm products, and potatoes in particular, can only be accomplished through an effective and comprehensive growers' organization for the purpose of pooling crops and selling them through some central selling agency. Whether such a millenium in the marketing of potatoes will ever be reached is difficult to say. The present trend of thought and action is in that direction. This is evidenced by the recent formation of a number of strong farmers' coöperative organizations.

QUESTIONS ON THE TEXT

1. What are the chief factors involved in harvesting the potato crop?
2. What fixed period in the growth of the crop do the data of harvesting represent?
3. What determines the date of havesting?
4. How do the southern and northern dates differ?
5. What two general classes of harvesting implements are used?
6. Name the hand implements that may be used.
7. Name and describe the non-elevator types of diggers.
8. How is the ordinary plow used?
9. How do potato diggers 2 and 3 operate?
10. How does class 4 implement differ from 2 and 3 in its operation?
11. What can you say of the number of types of elevator potato diggers?
12. What are some of the outstanding features of difference in their construction?
13. Why are four horses necessary to operate them in some sections and not in others?
14. Describe the gasoline equipped digger. What is the function of the gasoline engine in the operation of the digger?
15. How may the cutting and bruising of the tubers by diggers be minimized?
16. How does fast driving increase the amount of tuber injury?
17. How important is it to lower the rear rack or conveyor belt? Why?
18. How do practices differ in different sections of the country with respect to picking and handling the tubers?
19. Describe the Maine method of picking and handling the crop.
20. Describe the New Jersey method of picking and handling the crop.
21. How does western New York handle the crop?
22. In the West and in some sections of the South how is the crop usually gathered?
23. What is the practice in the tule lands of the Stockton, California, district?
24. What is the cost of picking potatoes?
25. What impetus did potato grading receive during the war?
26. What can you say of its probable permanency?
27. Describe the grades advocated by the U. S. Department of Agriculture.
28. Of what importance is it to the grower to have his potatoes properly graded?

29. Describe the operation of the belt conveyor type of sizer.
30. Describe the operation of the western type of sizer.
31. Describe the hand screen or sizer and tell how it is operated.
32. What do the Maine growers use as an aid in the operation of grading potatoes? Is it in any sense a sizer?
33. Discuss grading for a fancy trade.
34. What are the sizes of tubers suggested?
35. What are some of the advantages of having potatoes separated into uniform sizes?
36. Of what advantage would it be to the retailer to handle potatoes in small packages?
37. Of what advantage to the consumer from the quality standpoint?
38. Is the average grower ordinarily able to successfully market his crop? Give reasons.
39. What kinds of containers are used in shipping the crop to market?
40. Describe and explain the respective merits of each container and reasons for its use.
41. What are the chief objections to large sacks?
42. What trouble is caused from the use of sacks of varying capacities?
43. What objection is there to the use of the hamper? Where used?
44. How should double-headed stave barrels be loaded in a car?
45. Should burlap-covered barrels be loaded in the same manner as the double-headed barrels? Why?
46. How should summer shipments in sacks be loaded? What type of car?
47. How does autumn or winter loading of cars differ from summer loading?
48. How may box cars be made suitable for use in cold weather?
49. What are some of the difficulties involved in the marketing of the early or truck crop?
50. How has the development of large commercial production centres influenced the marketing problem?
51. Why is the marketing of the late crop of potatoes a less difficult problem?
52. How is the grower to determine when it is the proper time to sell?
53. To what extent is the railroad a limiting factor?
54. Why should the commercial grower make provision for the storage of his crop?
55. What would be the ideal method of marketing the crop?
56. How may the price of potatoes be stabilized?
57. What is the present trend of thought in this direction?

QUESTIONS SUGGESTED BY THE TEXT

1. At what stage of growth do the local growers harvest their potatoes?
2. List the methods of harvesting used locally, in order of popularity.
3. Which methods are least injurious to the tubers?
4. Describe local methods of picking and handling potatoes.
5. From local growers ascertain the cost of picking potatoes.
6. What grading and sizing is done locally? Give methods.
7. Describe local methods of shipping and marketing.
8. What containers are used?

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CHAPTER XIII

POTATO STORAGE AND STORAGE SHRINKAGE

As the agricultural and economic importance of perishable food products increases in any given community, state or country, the question of storage at once enters into the problem of their conservation and distribution throughout the period in which these crops are not normally produced.

The relative ease with which the potato can be held in storage during the winter months in the northern section of the United States and Canada, or, under similar climatic conditions, in other portions of the world, has not served to stimulate any very careful study looking toward the determination of the optimum storage conditions for this crop. In view of the fact that the quantity of potatoes annually stored for winter and spring use is relatively large, it would seem that we should know more than we now do about the actual shrinkage that is likely to occur under certain conditions during a given storage period.

Object of Storage.—The primary object in the storage of any product is that of prolonging its edible stage of maturity throughout a longer period of time. The secondary, though by no means unimportant, object of storage is that of minimizing the losses occurring during the storage period. The chief sources of shrinkage in storage result from moisture losses and decay Storage makes it possible to hold over the late or main crop of potatoes in the North throughout the winter and spring months, thereby enabling the grower or the dealer to dispose of the crop at such times as the requirements of the market demand, and by so doing avoid marketing it when there is an over-supply and consequently low prices.

The successful storage of potatoes is dependent upon a number of factors among which may be mentioned temperature, humidity, aeration, exclusion of light, soundness of tubers stored, freedom from dirt and moisture, and, last but not least, size of the pile.

Storage Temperature.—There are many current notions regarding the best temperature at which to store potatoes, but until quite recently there have been few experimental data upon which to base conclusions. This has been particularly true with respect to seed stock.

The following opinions are given with a view of presenting such information as we have at the present time. Cooper[3] recommends a temperature of from 33 to 35 degrees F. as about right for potatoes. Fraser,[6] in discussing ventilation and temperature, says "The potato must be kept cool, about 33 degrees being a favorable temperature." Corbett[4] recommends a temperature of 34 degrees as a minimum and 45 degrees as a maximum throughout the entire storage period. Grubb and Gilford[7] believe that in winter the temperature of the potato storage house should be kept as near 32 degrees as possible. In this connection they say, "It is best when it does not go below 30 degrees nor above 36 degrees." Wright and Castle,[11] in their discussion of storage, mention the investigations of Dr. Parisot, a French scientist who, as a result of his studies, recommended 46 degrees as the ideal storage temperature for potatoes in winter. Appleman[1] found in some recent investigations that ordinarily the freezing temperature of the potato lies between 28 and 26 degrees. Some years ago the writer, while conducting potato investigations at the Vermont Station, used a basement cellar for storage purposes in which the temperature on a number of occasions dropped to 30 degrees and on one occasion went as low as 28 degrees. Aside from a rather tardy germination of the seed when planted, no ill effects were noted from these low temperatures. Since 1911, a considerable portion of the seed potatoes produced by the Office of Horticultural and Pomological Investigations of the United States Department of Agriculture have been stored in an artificially refrigerated room in which the temperature could be varied as desired. It has been the custom in storing potatoes in this room in the fall to reduce the temperature as rapidly as possible until it reached 40 degrees after which it was held at that point until about February 1, when the temperature was gradually lowered until it reached about 35 degrees. Usually the temperature was allowed to fluctuate between 37 and 35 degrees. This practice has served to hold the tubers in perfect condition so far as firmness and dormancy are concerned. Remembering that the sole function of storage is to preserve the stored product in as nearly its original condition as possible, it would seem that the maximum temperature at which the tubers can be held and still remain firm and dormant should be regarded as the most desirable one to use.

Butler's studies[2] led him to conclude that a temperature of 3.74 degrees C. or approximately 39 degrees F. was sufficiently low to retard germination indefinitely. He also found that germination could be more completely arrested in air nearly devoid of oxygen (dead air) at a temperature of 9.31 degrees C. (practically 44 F.) than in free air at 3.74 degrees C. In a later publication Butler[2a] says, "The temperature of storage for domestic use should be 46 degrees F. or as near this temperature as is consistent with proper keeping. At lower temperature than 46 degrees F. potatoes become more or less sweet and watery, conditions that are, culinarily, very undesirable. Storage in dead air is open to the same objection as storage at low temperature."

Recent studies, undertaken by the writer in the fall of 1918, and continued throughout the whole of 1919, have demonstrated that the germination of potatoes can be arrested when stored at a temperature of 40 degrees F.

Conclusion.—A temperature of about 36 degrees is sufficiently low for all practical purposes, and in the earlier stages of the storage period a temperature of 40 to 42 degrees is probably just as efficient as a lower one.

When potatoes are first stored every effort should be made to reduce the temperature as quickly as possible. This is particularly desirable if the weather is warm when they are dug, as they absorb heat readily and also develop heat rapidly when stored in bulk under the conditions mentioned. In natural storage this is most easily accomplished by a little attention to the opening of doors and ventilators in the evening, when the nights are cool, and closing them early in the morning.

Chemical Effects of Low Temperature on the Tuber.—It has long been recognized that when potatoes are subjected to temperature in the vicinity of the freezing point of water, 32 degrees F. for any considerable period there is an appreciable accumulation of sugar in the tuber which, when cooked, imparts or a more or less sweetish taste to the flesh. This condition of the tuber may or may not be objectionable, according to whether it is or is not intended for immediate table use or removal from storage. In some recent studies by Appleman (*l.c.* p. 330) it was found that the exposure of these tubers for a week to a temperature of from 70 to 75 degrees was sufficient to transform four-fifths of the sugar accumulation into starch. These results would indicate that a sugar accumulation in potato tubers is not such a serious matter, unless they are desired for immediate use. The phenomenon of sugar accumulation in the potato is an interesting one, because it is a direct result of throwing the life processes, continually going on within the tuber, out of equilibrium through a lowering of the temperature. Appleman says (*l.c.* p. 330), "At 46 to 50 degrees F., the process of respiration and synthesis (in the potato) of starch from sugar consumes all the sugar that is formed by the action of the diastase; therefore no sugar accumulates. Below this temperature, the two former processes are inhibited to a much greater extent than the latter; consequently sugar begins to accumulate. At 32 degrees F. respiration and starch synthesis are so slight that a large percentage of the sugar formed accumulates; the supply is greater than the consumption."

Humidity.—Very little information regarding the proper degree of humidity to maintain in the storage house or room is available. The question as to whether the humidity content of the air should be high or low is one to which the data at hand do not permit a satisfactory answer. In all of the storage work with which the writer has been associated, an attempt has been made to maintain sufficient moisture in the air to keep the tubers firm, and at the same time not have it so saturated as to produce a film of moisture over the surface of the tuber. Cooper (*l.c.* p. 503) suggests a humidity of from 85 to 90 per cent as about correct for a potato storage room when the temperature ranges from 33 to 35 degrees F. This suggestion coincides with our own observations as, under the conditions which have been mentioned, it has been found that the humidity content of the air was approximately 85 per cent. It would, therefore, seem that until further light has been thrown upon this subject as a result of careful experimental studies, it is safe to advise an air saturation of about 85 per cent. One can, of course, conceive of a condition where it might be unwise to keep the air as moist as this. For example, where storage decays were present a drier atmosphere would tend to check the shrinkage from disease to a greater extent than that resulting from increased transpiration due to a drier air.

Aeration.—The importance of a good supply of pure air in the potato storage house has not, so far as we know, been demonstrated by any carefully conducted experiments. It seems reasonable, however, to assume that it can hardly be other than desirable from the health standpoint of the tuber. In order to insure an ample supply of pure air in the storage house or room, generous provision should be made for ventilation. Ventilators or air flues should be so provided as to insure a rapid and even distribution of air throughout the structure. The European grower finds it advantageous to store seed potatoes in open crates or shallow trays which are stacked up in tiers, thereby insuring a free circulation

FIG. 109.—Seed potatoes stored in shallow trays or flats.

of air around the tubers (Fig. 109). Specially constructed bins may partially serve the same purpose. (See Chapter XIV on storage house construction.)

In potato storage house construction every effort should be made to exclude the light. Potatoes intended for table purposes should not be exposed to light any more than is absolutely necessary in the harvesting and storing of them. The quality of the potato is very quickly injured by light. An exposure of two or three days to strong light (not sunlight), very materially affects the eating quality of the potato, and a long exposure to even a very weak light is also injurious. The storage house or room should be kept as dark as possible, if the quality of the potato is to remain unimpaired.

Potatoes intended for seed purposes are not injured by light, in fact many of the best European growers purposely expose their seed stock to the light under the firm conviction that it starts them into growth quicker and makes more vigorous plants.

On the subject of aëration Butler[2a] says, "Aëration should be sparingly given and the air should flow in at the bottom of the bins, not from the top. Cold air holds less water than warm air, and cooling the top of a bin results in a deposition of moisture, or the maintenance of too high an atmospheric humidity." This statement is somewhat at variance with accepted notions concerning aëration, though more or less in keeping with present practices, so far as moderation in the amount of air admitted into most commercial or farm storage houses. The admission of fresh air through the floor of the cellar is in line with what is already embodied in the United States Department's storage house on Aroostook Farm, Presque Isle, Maine. Fresh air is brought into this house through an 18-inch concrete conduit which discharges its flow of air through an opening in the center of the driveway. The warm air is removed from this house by means of two large ventilators connecting with roof cupolas (Fig. 133).

Soundness of Tubers Stored.—One of the most prolific sources of loss in storage is that resulting from the storing of unsound tubers. Unsound tubers may be classified under two heads: (a) Those that are mechanically injured such as bruised or cut tubers; (b) those that are infected with disease, such as the late blight rot and the powdery dry rot. The losses resulting from mechanically injured tubers are very largely dependent upon storage house conditions; for example, if the temperature and humidity are high, the shrinkage will be much greater than if the temperature and humidity are approximately right. Much also depends upon the sanitary condition of the storage room. If the storage house has been carefully disinfected before placing the potatoes in it, the chances for infection of the cut or bruised surfaces are largely eliminated. If, however, unsanitary conditions prevail, the presence of cut and bruised surfaces offer an easy point of infection for a number of storage decay organisms. The more carefully, therefore, that potatoes are harvested and stored, the better will be their keeping qualities and the less the shrinkage.

Every effort should be made to remove all diseased tubers from those intended for storage purposes. Ordinarily, the late blight rot is the most serious storage trouble in the northeastern part of

North America, while the powdery dry rot is probably the worst in the western states. In regions where late blight is likely to be prevalent, it should be so controlled by the thorough spraying of the growing plants as to effectually prevent tuber infection. In any case, however, every effort should be made to remove disease-infected tubers before placing them in storage.

Freedom from Soil and Moisture.—While it is recognized that it is not always possible to harvest the potato crop in such condition as to insure freedom from any unusual amount of soil, it is believed that, insofar as it is consistent with the safety of the crop, harvesting operations should be so timed as to insure a minimum amount of soil adhering to the tubers. It is not a good practice, if obliged to harvest the crop when the soil is too wet for good results, to gather the tubers as soon as dug. Advantage should be taken of every opportunity to leave them exposed to the sun and wind for an hour or more, in order to allow the excess moisture to dry off and to get rid of as much excess dirt as possible. When potatoes are stored with large quantities of moist soil adhering to the tubers, they are almost certain to develop a considerable amount of heat, especially if stored in bulk. Piles of potatoes stored in this condition may cause as large a volume of steam to escape as might ordinarily be expected from a pile of fermenting manure. It requires very little imagination on the part of any thinking person to figure out that potatoes stored under such conditions are much more likely to decay; and even if no decay does occur, to realize that when the tubers are subjected to such high temperatures, the transpiration losses are very greatly increased. Let us not forget, therefore, that dirt and moisture are undesirable factors in potato storage, and make every effort to store clean and dry tubers.

Size of Storage Pile or Bin.—It is a bad practice to store potatoes in large piles or bins without some provision being made to ventilate the pile. In many instances, potatoes are piled to a depth of from 10 to 15 feet and correspondingly large in the other two dimensions. If the tubers are reasonably dry, free from dirt and well ripened, no serious harm may result from storing in such large piles. Under such conditions, whatever injury they may sustain will be incurred in putting them in the storage house or bin, and the crushing or cracking of those at the bottom of the pile by the excessive weight of those above. On the other hand, if the crop is harvested when the ground is wet, and goes into storage under the conditions mentioned in the preceding paragraph, it is dangerous to store to a greater depth than six feet; if the bin or storage space is a large one, ventilator shafts should be inserted in it at intervals of six to eight feet apart. These shafts are easily constructed and may be of any diameter desired. They may be either square or rectangular in shape. If square, a dimension of 18 by 18 inches, or 24 by 24 inches will be found convenient. A simple form of construction consists in the use of 2 by 4 uprights as corner supports, upon which are nailed four or five-inch strips of inch lumber, so spaced as to give one to one and a half inch openings between each strip. These air shafts may be made any height desired, and should be placed in position as the bin is filled. Another method is to use ventilated division walls, so constructed as to leave an air space in the centre of the wall, see figure 109 in chapter on storage house construction.

Storage Shrinkage.—The shrinkage involved in the storage of potatoes from Autumn until late Spring may vary from less than 4 to over 20 per cent by weight, depending upon the type of storage house used, the care given to maintaining the proper temperature and humidity, and the condition of the tubers when placed in storage. The natural and inevitable losses in storage are those involved in the transpiration and respiration processes continually going on in all living matter.

Shrinkage Due to Transpiration and Respiration.—Comparatively little attention has been paid to the moisture shrinkage of potatoes in storage, by the potato growers of the United States, and, with but one or two exceptions, such data as have been published are not of scientific value, as they do not represent carefully observed temperature and humidity conditions in the storage room.

An examination of the literature on the subject disclosed the fact that French and German investigators have made a more or less careful study of the question and, in some respects, have secured very interesting data. For the most part, however, their observations were made on tubers stored at a much higher temperature than growers in this country would consider suitable for the potato. The temperatures at which most of their experimental work was conducted varied from 43 to 52 degrees F., and, in some instances (Nobbe's), much higher than this.

Foreign and American Investigations.—In 1865, Nobbe[8] reported the results of his experimental studies concerning the loss of water and carbonic acid gas from potato tubers in storage. His studies covered the period between December 12 and June 7. Unfortunately, Nobbe's observations were based on but two selected tubers in each lot studied, a quantity much too small for experimental purposes. It is thought desirable, however, to present it, in order to show the character of the data taken. Nobbe so arranged his experiment that it involved eight separate conditions, or factors. Each of the eight lots of tubers was subjected to the following factors:

	Decrease in Weight
1. Cool-dry-light (50 to 61 F.)	34.05 grms.
2. Warm-dry-light (77 to 95 F.)	57.25 grms.
3. Cool-moist-light	20.15 grms.
4. Warm-moist-light	57.65 grms.
5. Cool-dry-dark	34.45 grms.
6. Warm-dry-dark	63.25 grms.
7. Cool-moist-dark	13.35 grms.
8. Warm-moist-dark	62.10 grms.

Inasmuch as Nobbe fails to state the original weight of each lot of tubers, the data given lose much of their significance, as it is impossible to compute the actual percentage loss. The significant factor determining loss is temperature. Light influence in this experiment appears to be a negligible one. In the case of dry versus moist-storage air conditions, an appreciable decrease in weight is noted for those stored in dry chambers. An interesting feature in Nobbe's paper is that pertaining to his determination of the relative proportion of moisture and carbonic acid gas loss in storage. According to his figures, the ratio of gas to water is 1 to 3.5.

Mertzel and Lengerke's Agricultural Calendar for 1891, p. 151, contains data regarding the decrease in weight of 100 kilos of potato tubers in storage, but does not vouchsafe any information regarding the source of the data. The observations, as reported, extend from the end of October to the end of May. The percentages of loss in weight are presented by months.

November	.56 per cent.
December	2.58 per cent.
January	1.00 per cent.
February	1.40 per cent.
March	1.06 per cent.
April	1.40 per cent.
May	2.00 per cent.
Total loss	10.00 per cent.

In 1891, Wollny,[10] after reviewing Nobbe's investigations at some length, presents the results of his own studies on the moisture loss sustained in storage of a dozen varieties of potatoes. His observations were made on 100 carefully selected tubers of each variety during the period from October 5 to May 1. Each lot was weighed at the beginning of the experiment, after which the potatoes were placed in tin containers and stored in a dry, deep cellar, in which the proper light, and a rather constant temperature (from 43 to 52 degrees F.), were maintained. The subsequent weighings were made on the first and fifteenth of each month.

The total loss in weight for each variety during the whole period was as follows:

Blue Princess	4.55 per cent.
Six Weeks	4.87 per cent.
Late Rose	5.27 per cent.
Gold Else	5.43 per cent.
Sovereign	5.71 per cent.
Early Rose	6.07 per cent.
Marmont	6.46 per cent.
Achilles	6.49 per cent.
Snowflake	6.65 per cent.
Lubenauer	6.78 per cent.
White Rose	7.28 per cent.
King of the Earlies	8.48 per cent.
Average loss	6.17 per cent.

Wollny's conclusions were that the reduction in weight of potatoes in storage in a cool, dry, and moderately light place, is greatest immediately after harvest, diminishing continually from that time until March, but increasing from then on.

He concluded also that the apparent differences in percentage loss between the different varieties of potatoes during storage do not stand in any conformable relation to the size of the tuber, nor to the length of the vegetative period of the variety.

Denaiffe,[5] in 1907, reports a somewhat similar investigation to Wollny's. His studies included eight varieties, on which he observed the decrease in weight of tubers for a period of about 14 months. The quantity of each variety used was 100 kilograms, on which readings were taken each month.

In discussing his data, Denaiffe states that the loss in weight during storage varies with the varieties, and is not the same for all months.

The losses sustained by each variety from December 1, 1904, to June 1, 1905, were as follows:

Up-to-date	5.0 per cent.
Imperator	5.15 per cent.
Professor Maercker	6.55 per cent.
Quarantaine de la Halle	6.60 per cent.
Parisienne	7.10 per cent.
Belle de Fontenay	7.30 per cent.
Saucisse rouge	9.35 per cent.
Royal kidney	9.50 per cent.
Average loss	7.00 per cent.

This observation is confirmatory of that of Wollny, and simply emphasizes the fact that all varieties do not give similar responses in storage. The maturity of the variety, the character of the skin, and its period of winter rest are factors which influence the activity of the transpiration and respiratory processes of the tuber. A comparison of these losses by months, as noted by Wollny and Denaiffe, indicates somewhat wide variations in the percentages of loss in weight under different environmental conditions and with different varieties.

Comparison of Wollny's and Denaiffe's data, giving percentage of loss by months:

Date	Wollny, (12 var.)	Denaiffe (8 var.)
Oct. 5 to Nov. 1	2.02 per cent.	——
November	1.18 per cent.	——
December	0.75 per cent.	1.125 per cent.
January	0.50 per cent.	1.193 per cent.
February	0.81 per cent.	0.725 per cent.
March	0.41 per cent.	1.218 per cent.
April	0.50 per cent.	1.0 per cent.
May	——	1.743 per cent.

Given similar conditions and varieties, well-ripened tubers should not show any appreciable loss in weight during the first few months of storage, provided a uniform and moderately low temperature is maintained.

For present uses, Wollny's data are more valuable, in that they account for the loss in weight from October 5, as against December 1 in Denaiffe's studies.

Taft and Hedrick [9] report a loss in weight on a barrel of potatoes, stored in a basement cellar from September 30 to March

28, of 5 per cent, and 6.5 per cent from March 28 to May 1—or a total loss of 11.5 per cent. It is self-evident that the heavy loss incurred during the latter period must have been the result of high temperature and possibly of germination. Fraser,[6] (p. 151), reports a loss of 12 per cent in Sir Walter Raleigh stored in crates in a cool cellar from November 6, 1903, to April 27, 1904, while under similar conditions, Carman No. 3 showed a decrease in weight of nearly 10 per cent.

Butler's studies,[2a] (p. 4), on the relation of temperature to loss in weight of Green Mountain potatoes placed in storage November 12, shows the following percentage losses for 30, 60, 90, 120, 150, 180 and 210 day periods at three temperatures.

Effect of Temperature on Respiration and Transpiration Losses from Potatoes.

Mean temperature of storage	Per cent of loss in weight after						
	30 days	60 days	90 days	120 days	150 days	180 days	210 days
39 degrees F.	0.58	1.43	1.43	2.29	2.58	2.15	2.44
48 degrees F.	1.26	2.53	3.37	4.21	7.18		
60 degrees F.	1.52	2.77	4.01	6.65	11.56		

A comparison was also made of the respiration and transpiration losses from two lots of Green Mountain potatoes removed from ordinary storage on January 26 and subjected to a temperature of 50 degrees F., one lot being exposed to a free circulation of air, while the other was stored in dead air. The percentage loss at the end of 90 days was 8.96 from those in free air and 1.35 from those in dead air. At the end of 119 days, these percentages had increased to 17.24 and 2.79 respectively. Those exposed to free air began to germinate in 43 days, while those in dead air remained dormant.

Numerous inquiries by the writer regarding potato storage losses have invariably elicited from the grower or shipper the reply that no definite effort has been made to determine the losses, either collectively or separately. It is the general impression that the losses from moisture and decay vary from 10 to 20 per cent. Under exceptionally good storage conditions, transpiration and respiration losses of less than 4 per cent have been reported. Such losses do not, of course, take into consideration those involved in the germination of the tubers. In the process of germination both the respiration and transpiration processes are quickened, because the temperature of the room must be relatively high to permit of germination; and, in addition to this, the starch content of the tuber is very rapidly transformed into sugar. Under these conditions, the shrinkage is heavy and the quality of the flesh rapidly deteriorates.

QUESTIONS ON THE TEXT

1. What is the primary object of storage? Secondary object?
2. What are the chief sources of loss during the storage period?
3. In what sections of the country is potato storage of the greatest importance? Give reasons.
4. Upon what factors is successful storage dependent?
5. Upon what are based the data regarding the proper storage temperature for potatoes?
6. What does Dr. Parisot regard as the ideal temperature?
7. What is the freezing temperature of the potato as determined by Dr. Appleman?
8. What temperatures were found satisfactory by the Office of Horticultural and Pomological Investigations during the past several years?
9. On first storing potatoes, what attention should be given to the manipulation of the storage house?
10. What is the chemical effect of prolonged low temperature on the potato tuber? How serious is this?
11. How may such an effect be dissipated?
12. What information have we on the subject of humidity in the storage house?
13. Of what importance is the question of aëration on potato storage?
14. What are Butler's suggestions regarding aëration? How much are his ideas at variance with current notions?
15. Why should there be an effort made to exclude light from the storage house?
16. What is one of the most prolific sources of loss in the storage house?
17. Under what two heads may unsound tubers be classed?
18. What precautions should be observed relative to the exclusion of diseased or injured tubers?
19. Why have the tubers free from an excess of soil or of moisture before storing them? How?
20. What factors limit the size of the storage pile or bin?
21. What should be the limiting factors governing the size of the pile or bin?
22. What percentage of shrinkage is usually entailed in storage?
23. What information have we upon the actual natural losses in storage?
24. What results did Nobbe secure from his storage studies?
25. What losses are shown in the data published in Mertzel's and Lengerke's Agricultural Calendar for 1891?
26. In Wollny's investigation of the moisture loss sustained in storage, what evidence is seen that he took proper precautions to secure desirable material for study?
27. What is there to show that the temperature at which the tubers were stored was sufficiently low to determine the minimum loss from transpiration and respiration?

28. Can you explain why the results secured show such variations in the percentage of loss of the 12 varieties studied?
29. What were Wollny's conclusions regarding the losses?
30. What was the nature of Denaiffe's investigations?
31. Compare the results secured by Denaiffe with those of Wollny?
32. From a scientific as well as a practical standpoint, which of the two sets of data has the greatest value? Give reasons.
33. What loss in weight did Taft and Hedrick observe in their experiment?
34. What loss did Fraser note in his studies?
35. What losses did Butler note in his investigations?
36. What is the general impression by growers and dealers regarding the percentage of storage loss?
37. Under good storage conditions and with sound stock, how low may the percentage of loss be?

QUESTIONS SUGGESTED BY THE TEXT

1. Do local growers or dealers store potatoes?
2. Ascertain the various lengths of storage periods.
3. What examples can you find of serious rotting and heating?
4. Obtain examples in homes or boarding places of potatoes that have become sweet or watery from storage.
5. Trace such example and determine, if possible, how and where stored, and temperature of same.

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CHAPTER XIV

TYPES OF STORAGE HOUSES, THEIR CONSTRUCTION AND COST

In the present discussion of types of storage, either in especially constructed storage houses or otherwise, it is our purpose to briefly trace its development from the primitive to the modern up-to-date artificially refrigerated structure. Storage in its primitive state consisted in burying the product in the soil, or storing it in a cave or excavated chamber of some sort. As agriculture developed, and became more specialized, and wealth increased, better and more expensive types of storage were demanded, in order to meet the growing necessities of large urban populations. In the case of the potato, one of the simplest and most primitive forms of storage, commonly known as pitting, is still practised to a limited extent in some sections of the country.

The types of storage to which consideration is given in the ensuing portion of this chapter embrace everything that may justly be regarded as applicable to the potato. The house cellar is omitted, because it is assumed that it does not require discussion or explanation, other than to say that in special late potato-producing sections it is not generally employed for storage purposes. The following types are believed to represent those that are now generally employed for potato-storage purposes:

1. Pitting.
2. The dugout, or cellar type of storage house.
3. The insulated wooden structure.
4. The Aroostook, Maine, type.
5. The artificially refrigerated structure.

Pitting.—Potatoes may be successfully stored in pits if good drainage is provided and sufficient covering applied to thoroughly insulate the stored tubers from external heat and cold. Strictly speaking, the term pitting is somewhat misleading; it does not necessarily imply an actual pit in the ground, as will be noted in the discussion that follows.

In pitting potatoes, good drainage is the first consideration in selecting the site. The land must either be well drained naturally.

or else so situated as to make good drainage possible. Little, if any, excavation is ordinarily made in pitting potatoes, aside from making a smooth surface on which to pile the tubers.

Fig. 110.—First steps in pitting potatoes.

Shape of Pile.—The shape of the pit should be that of a parallelogram, rather than square or circular. The customary practice is to pile the tubers in a ridge or inverted Λ-shaped fashion as

Fig 111.—Exterior view of a large potato storage cellar in process of construction on the Sweet ranch, Carbondale, Colorado, showing construction of vestibule entrance and the covering of roof with straw.

shown in (Fig. 110). When piled in this way, it exposes a greater area of the pile to the air and, when covered, sheds rain much better.

Its size is, of course, determined by the quantity of potatoes to be stored, and the limit of safety as regards danger from loss if stored in too large a pile; because, as the size of the pile increases, the difficulty of cooling it quickly is enhanced; and, should decay in the tubers become active, greater losses are sustained in large than in small piles. Generally speaking, the limit of size should be from 300 to 350 bushels or half a carload.

Fig. 112.—Interior view of same cellar showing roof construction and method of supporting it; also central driveway through the storage cellar. Messrs. Lou D. Sweet on the left and F. E. Sweet on the right.

Provision for Ventilation.—When pitting the tubers, some provision should be made for ventilation. A common practice abroad is to take a handful of rye or wheat straw and stand it in a vertical position on top of the pile while the straw and earth covering is being applied, after which it is pulled out, thus providing a vent for the escape of heat and moisture. Probably a better practice is to construct a small ventilator shaft of six or eight inches diameter out of inch lumber. Bore numerous holes an inch or so in diameter in the lower portion of the shaft, and insert it in the centre of the pile as the tubers are being pitted. The nearer it extends to the bottom of the pile, the more perfect the ventilation provided. It should extend three or four feet above the tubers, so that when the covering is applied it will protrude 18 to 24 inches above it. The ventilator should be provided with a cap to prevent the entrance of snow or rain. In severe weather it should be stopped with straw. If the pile is more than ten feet in length, a second ventilator should be inserted. A good rule to follow is to have a ventilator every eight feet. This insures reasonably good ventilation of all portions of the pile.

Fig. 113.—Completed structure showing cribbed vestibule on the Sweet ranch, Carbondale, Col.

Protection Against Frost.—As soon as the potatoes are in position, they should be immediately covered with a sufficient quantity of straw or marsh hay to exclude light. The pitted tubers should be left in this condition as long as they are safe from frost. This gives them a chance to go through the sweating process and get thoroughly cooled off, after which there is little danger from heating and sweating when the final covering is applied.

As soon as the nights become frosty, apply a heavy layer of straw, so that when compacted with soil it will be about six inches thick. On top of the straw apply a six inch layer of soil. Before the ground freezes too solid, apply another heavy layer of straw and a similar one of soil. Ordinarily, two heavy layers of both straw and soil furnish sufficient insulation; but where extremely cold weather prevails, a third layer may be advisable. When sound potatoes are pitted in this manner, there is practically no risk involved, as they are almost certain to come out in good condition in the Spring.

The advantage of pitting potatoes is that it is a cheap form of storage.

FIG. 114.—A good example of a sod-walled potato storage house near Greeley, Col This house is provided with ridge and side ventilators.

The disadvantage of pitting is that in severe weather the potatoes are not accessible, consequently any sudden rise in market prices cannot be taken advantage of by the grower.

FIG. 115.—One of ths cheaper types of partially sunken, earth-covered storage houses with earth retaining walls and side roof openings which may be used for filling the storage space or for ventilation. In the Greeley, Col., district.

Generally speaking, pitting is not to be recommended, except where no other storage facilities are available.

Storage Houses Proper.—In deciding what particular storage house is most suitable to one's needs, the following factors should be considered:

(a) The temperature and precipitation likely to occur during the storage period; (b) the character and cost of the materials involved; (c) the nature of the soil and drainage; (d) the storage period.

It is apparent to the reader, that, in the arid and semi-arid regions of the West, a materially different type of construction from that in use in the rain-belt section of the East might be permissible.

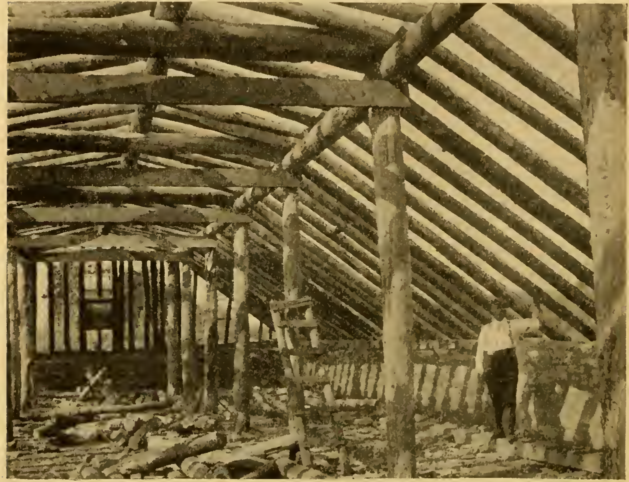

FIG. 116.—A well-constructed storage house of the partially sunken type with side and end walls of stone. Note heavy pole rafters covered with woven fence wire ready to be covered with straw and soil. In the Greeley, Col., district.

The Dugout or Cellar Type of Storage House.—In the central and western portions of the United States, the dugout or cellar type of storage house is almost the only kind employed in the storage of potatoes. It is found in its most primitive state in the arid and semi-arid regions of the West, and in its highest state of development in the north central tier of states where the heavier rainfall makes water-tight roofs a necessity.

Location and Construction.—The storage house should, whenever possible, be located conveniently to the dwelling house, because, in very cold weather, it usually requires rather close attention to guard against the entrance of frost. Where side-hills, knolls, or what are termed in the West "hog-backs," consisting of a narrow and usually short ridge of land, are available, it is advisable to take advantage of them, as by their use better drainage and a ground level entrance at either or both ends of the cellar can be secured (Figs. 111 to 119). Where the topography of the land is

Fig. 117.—A cheaply constructed storage house near Capeville, Va. Roof consists of rough poles resting on the ground and supported by ridge pole at top covered with pine needles. Such a type of storage house would not be suitable where extremely low temperatures prevail.

such that it does not furnish these natural advantages, level land may be used, provided good drainage can be secured. In this case, the excavation may vary from practically nothing where surface drainage must be depended upon, to five or six feet where there is good natural or artificial drainage. The average depth of the excavation for the cheaper structures of this type, when erected on level land, does not exceed three feet. The soil removed from such an excavation, particularly if the structure is wide, provides ample material for banking the side and end walls as well as for a roof covering.

Where the soil is of such a character as to remain intact, and an excavation of sufficient depth can be made, it is allowed to form the side, and in some cases the end walls; the roof being supported by plates resting on the soil and an occasional post to relieve the roof pressure. In such cases, the outward thrust of the roof is

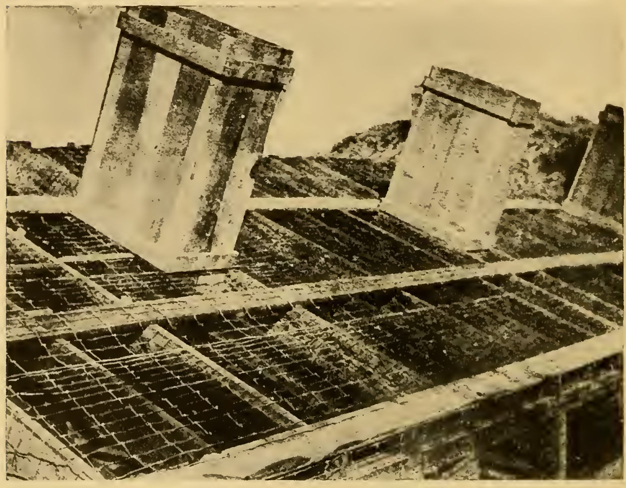

Fig. 118.—A storage house in process of construction at Aberdeen, Ida., showing side walls and roof covered with woven wire fencing and ventilators in side of roof.

cared for by cross-tieing the rafters with boards. Where the earthen bank of the excavation serves as walls to the storage structure, it is better to support the plate entirely with posts recessed into the earthen walls at sufficiently close intervals to afford the necessary strength, (Fig. 121).

Where the storage cellar is only partially below the level of the ground, the walls are variously constructed. In the cheapest type noted, both side and end walls above ground were constructed out of a tough sod of sedges or cat-tails cut to uniform size and laid up in brick fashion. These walls were two feet or more in thickness. The sod walls supported the plates and roof in practically the same manner as in the case of the solid earthen-walled structure (Fig. 114). Another cheap structure is that shown in figure 117. In this instance the excavation was not over two feet, and the roof consisted of rough poles covered with a heavy layer of pine needles. Such a storage house has little to recommend it, except that of being a temporary makeshift to tide over a short storage period where the climate is reasonably mild.

Roof Construction.—The roof of the cheaper types of houses is usually constructed out of undressed poles, which may be laid sufficiently close together to serve as a support for a brush or straw

Fig. 119.—Side view of the house shown in Figure 118, with roof covered with straw and soil and ventilators capped.

covering, over which a heavy layer of soil (6 to 10 inches) is placed. In the better constructed houses in the semi-arid regions, heavier and more substantial rafters are used, and they are spaced about twelve inches apart. After the rafters are in place, a heavy woven wire netting is stretched over them and nailed in place, (Figs. 116 and 118), and over this the usual straw and earth covering is applied.

Where a side hill or a "hog-back" is available, the cut or excavation may be six to ten feet in depth, depending on the size of the structure. Such a site makes it possible to provide a ground level entrance, at one end of the storage house in the case of the side hill, and at both ends when advantage can be taken of a "hog-back" (Fig. 113).

Wall Construction.—In addition to the cheaper types of wall construction previously mentioned, it is well to consider those of a more permanent nature. These may consist of rough or dressed posts set from four to six feet apart, covered on the outside with rough poles, lumber or heavy woven wire; or they may be constructed of masonry or concrete. The style of wall construction adopted is very largely a matter of choice or necessity. Where first cost is not a serious consideration it is, without doubt, more economical to build a substantial structure. The grower should not, however, lose sight of the fact that the cheaper house, if carefully built, will provide as good storage as the more expensive one as long as it lasts. A partially sunken house is shown in figure 122.

In the humid regions of the north central and eastern portions of the United States, where heavy rains would render straw and

Fig. 120.—A frontal view of the completed potato storage house (Fig. 118) showing driveway entrance and ventilator caps raised on left side.

earth-covered storage houses unsatisfactory, they are constructed with a water-tight roof. Generally, the roof is covered with rough lumber, tar paper and shingles. Occasionally, it is sheathed with matched lumber on the inside. This treatment provides a fairly well insulated roof which in winter requires no additional protection, except during extremely cold weather, when a light covering of straw or strawy manure is advisable.

The wall construction of the water-tight roof storage house need not necessarily differ from that of the semi-arid region type except that, on account of the heavier rainfall, it must be built sufficiently strong to prevent a cave-in. Where first cost is subsidiary to durability, it is generally advisable to use a better class of lumber than the rough undressed poles. It may even be economy, where the materials are available, to construct the side and end walls of concrete (Fig. 123). In some of the better type western potato storage houses observed, the posts were faced on two sides and the walls as well as the roof were covered with woven wire and straw, (Figs. 118, 119 and 120).

The use of straw on the roof, especially when the rafters are spaced and covered with woven wire, serves not only as a protection

FIG. 121.—View showing earthen wall with plate supporting posts recessed into the bank. On the Sweet ranch, Carbondale, Col.

against heat and cold, but is also a medium for the absorption of moisture given off by the tubers in the process of transpiration and respiration. There is no drip from such a roof.

Entrance Way.—Whether the entrance to the storage cellar is for team or man, on the level or an incline, (Figs. 113 and 120), it should be provided with two sets of doors with a vestibule between (Fig. 113) in the case of a ground level entrance; or bulkhead doors where it is not (Fig. 120).

Ventilation and Lighting.—Ample provision should be made in all dugouts or storage pit cellars for ventilation and lighting, where electric lighting is not feasible. Many styles of ventilators may be found, but those shown in figures 114, 115, 118 and 125 are most favored. A ventilator should be so constructed that it possesses ample size to admit an abundance of air, and at the same time be provided with a swivel or slide damper which may be closed in severe weather. A shaft with an interior diameter of 12 by 12 or 12 by 16 inches should be sufficiently large. Those with hinged caps to exclude rain, snow, or frost, seem to be preferred. As a rule, the ventilators are placed along the ridge of the roof, although numerous structures have been noted in which they were constructed about midway between the ridge and the plate. See figures 118 and 123 for both positions.

FIG. 122.—Partially sunken storage house with concrete side and end walls. Jerome, Idaho.

To insure uniform ventilation, they should be spaced from ten to twelve feet apart.

Interior Arrangement.—The interior arrangement of the storage cellar is very largely governed by its size and character. Where no driveway entrance is provided and the house is narrow, say 12 to 20 feet, the entire space is used for storage purposes. The dirt floor may be left uncovered; or it may be floored over with rough lumber or cemented.

In some of the better types of storage cellars in which there is a central driveway, the storage bins on either side of it have ventilated wooden floors laid on joists. The joists, being placed at right angles to the driveway, provide an open space between the floor and the earth beneath, and this, as will be seen later, furnishes an open and unrestricted circulation of air beneath the bin, (Fig. 109). Where posts are used which are faced on two sides, the inner face is boarded up with three or four-inch strips of lumber, leaving an inch space between each two strips. The division walls between the bins are also ventilated, in the manner described for the ventilation of potatoes when stored in large piles. With such a type of bin construction, a free circulation of air is possible on all sides. Of course, it is realized that the extra expense involved in bin construction of this sort is considerable; and it is probably not wholly justified, except for the storage of seed stock, or in seasons when frequent rains during the harvesting period make it impossible to dry the tubers properly before storing them. Under such conditions, the ventilated bin is decidedly superior to the ordinary type.

Fig. 123.—Potato storage house with concrete walls, straw and earthen-covered roof plus a superimposed wooden shingle-covered roof. Greeley, Colorado.

Where no provision is made for a driveway into the storage cellar, either because it is too narrow or for any other reason, the potatoes may be spouted into the cellar through the trap-door openings in the roof, (Figs. 126, 127 and 128). This method of filling the storage cellar is a material saving of labor, and, where a blanket or apron is used in lowering the potatoes from the spout to the floor, they sustain no more mechanical injuries than when unloaded directly from the driveway, or carried in by hand.

The Insulated Wooden Potato Storage House.—This type of house is not used very extensively. It is better adapted to southern than to northern climatic conditions. The construction feature of such a storage house is the thorough insulation of its walls, ceilings, doors and windows, (Fig. 129).

The type of house recently described by Thompson[2] for the storage of sweet potatoes will serve equally well for the Irish potato, but, in the case of the latter, does not require artificial heat to ripen the tubers. Storage houses of the type under consideration must, in the North at least, be provided with facilities for heating them in extremely cold weather. This may be done with an ordinary heating stove. They are not to be recommended for northern conditions, nor advocated for the South, except in localities where poor drainage conditions will not permit of the dugout or cellar type of storage house. They are not recommended on account of their greater cost of construction, and also from the fact that they do

FIG. 124.—A typical Red River Valley potato warehouse with a deep cement-walled basement cellar. Glyndon, Minn.

not furnish as good storage as a properly constructed cellar storage house.

The Aroostook, Maine, Type.—In northern Maine, particularly in Aroostook County, a type of potato storage house has been developed which may be said to be exclusively confined to Maine. While in a sense it is a cellar storage house, yet viewed from another standpoint it is more, because the true Aroostook storage house includes a superstructure over the cellar. It is always constructed on a side hill or knoll, and is always provided with a ground level driveway into the basement, and at the opposite end has a driveway into the superstructure above, (Figs. 130, 131 and 132).

Construction.—A considerable proportion of these storage houses are constructed with concrete basements and always with a wooden superstructure. When the basement walls are not built of concrete, they may consist either of a masonry wall of stone, a dry wall, or a wooden wall constructed with posts and rough siding, or it may consist entirely of rough posts. The floors may or may not be cemented. Usually, the storage space is covered with a tight wooden floor laid on joists.

The basements are usually of good depth, 8 to 12 or more feet, and their capacity ranges from 2,000 to 10,000 or more barrels. Generally speaking, their construction is faulty with respect to ventilation, only an occasional one being provided with means for ventilation, other than through trapdoors in the upper floor. The storage house with ventilator, shown in figure 130 was the only one the writer had noticed prior to 1917. See the ventilators in figure 133.

FIG. 125.—A 100,000 bushel potato warehouse at Larimore, N. D.

In storing the crop in the basement, the bins are partially filled from the lower floor, the balance being put in from above, through trapdoors on either side of the driveway and over the bins below. When the house is built with a central driveway, it may also be filled in the same manner.

In addition to serving a useful purpose in filling the bins and protecting the potatoes from inclement weather, the wooden superstructures of these storage houses have various uses, such as the housing of farm implements, barrels, sacks, fertilizer and other supplies; or they may serve for the storage of hay or grain.

Interior Arrangement.—Broadly speaking, the interior arrangement of the basement is dependent on whether it is constructed with a central driveway, or whether the entrance is at one corner of the building. A basement with a central driveway has bins on either side, whereas those with an entrance at one corner vary considerably in their bin arrangement, depending on whether one or more varieties are being grown and stored; figures 130 and 131 give a very good general idea of the exterior appearance of the Maine type of storage house.

The Artificially Refrigerated Potato Storage House.—This type of storage house, for potatoes at least, can hardly be said to be in existence. So far as we are aware, the present use of artificially refrigerated storage houses is practically confined to the holding of northern grown seed potatoes in cold storage for second crop planting in the South, and to the temporary holding of table stock in large distributing centres.

Fig. 126.—A good example of the type of storage house in use in the Red River Valley in Minnesota and North Dakota. This house has a water-tight roof with several openings in it to permit of spouting the potatoes into the storage bin. Sabin, Minn.

Ammonia System.—The system of refrigeration used in the cold storage plants employed for this purpose is known as the "ammonia system." The temperature at which potatoes are held in this type of storage is usually from 32 to 34 degrees F.

While there is probably little demand for the artificially refrigerated potato storage house in the North, it is a questionable point whether community cold storage plants could not be profitably employed by the southern potato truck grower. If such houses were available in the South, the present practice of moving seed stock from northern Maine during the months of January and February, with its attendant risk of frost injury could be avoided, as, with cold storage facilities, the seed potatoes could be shipped in the Autumn. At the present time, the potato storage houses of the South do not compare at all favorably with those of the North, being for the most part of the dugout type and constructed with little head-room. They are wholly inadequate for the holding of northern grown seed and, as a result, the stock held in them from November to February is usually rather badly germinated. All of these troubles could be avoided through autumn delivery of northern seed stock and its transference to the cold storage house. Such a change in time of delivery would enable the grower to purchase his seed at a reduction in price over that of mid-winter delivery more than sufficient to offset the cost of storage.

Brine System.—One of the more recent types of storage houses, which may have a place in the storage of potatoes outside of the colder potato-growing regions, is that known as "the Cooper system

FIG. 127.—Spouting potatoes into storage cellar through chutes in the roof, in the Greeley, Col., district.

of brine circulation." In this system, ice and salt are used as a substitute for ammonia in cooling the brine. In "Practical Cold Storage," pp. 660-662, Cooper describes the process as follows: "In the Cooper gravity brine system, the tank, which contains the ice and salt, and the tank coils, or primary coils as they are called, are located at a higher level than the secondary coils which do the air cooling in the rooms......When the tank is filled with ice and salt, the brine standing in the primary or tank coil is cooled, by contact with the ice and salt which surround the pipes, to a lower temperature than the brine contained in the secondary coils. At the same time, the brine from the secondary coils rises into the primary coils, where, as it is cooled, it repeats the circuit...... The term 'gravity,' as applied to this system of brine circulation, refers to the cause of circulation which is owing to the difference in specific gravity (weight) between the cold brine in the primary coils and the comparatively warm brine in the secondary coils. The temperature of the circulating brine will range from zero to 20 degrees F. It is comparatively easy to cool a room to 10 or 12 degrees F. with the Cooper brine system."

This system of refrigeration was used by the United States Department of Agriculture in the storage of potatoes from 1911

FIG. 128.—Method of filling a storage house in the Greeley district through openings in roof. Driveway partially filled by spouting potatoes through roof openings.

to 1918 and it proved very satisfactory. It was found possible, with proper attention, to maintain the temperature of the storage room at practically the same degree for weeks at a time, as shown by the thermograph record sheet (Fig. 134).

Cost of Construction.—Owing to the wide variation in cost of building material, and the price of labor in different sections of the country, cost figures concerning the construction of any particular type of house must, of necessity, be more or less general in their character. Naturally, the type and the size of the house is largely determined by the character of the material available, the climatic conditions and the storage capacity required. In determining the size of storage cellar required to house a given quantity of tubers, the estimate should be based on 40 pounds of tubers per cubic foot of available storage space. Figured on this basis, a bin 10 by 10 feet square, filled to a depth of six feet, has a storage capacity of 400 bushels, or an average of four bushels for every square foot of floor space.

FIG. 129.—A good example of an insulated wooden structure used for the storage of potatoes in some localities in Michigan.

Colorado.—The following information concerning the cost of construction has been very kindly furnished by practical growers. The first data presented are those given by Messrs. Lou D. and Frank E. Sweet, of Carbondale, Colorado, and relate to the potato storage house shown in figure 112. The capacity of this house is stated to be from 13,000 to 25,000 bushels, depending on the depth to which it is filled, as well as storing in the driveway. Its cost is estimated at $1,000. This cost did not include the lumber cut on the surrounding mountains, for which there was no other cost than that of cutting and hauling. Allowing $300 for the rough timbers used, it would bring the actual cost to about $1,300. On this basis, the initial cost of providing storage for one bushel of potatoes reduces itself from 10 to 5.2 cents per bushel, depending upon the depth to which the tubers are piled. Assuming that the average life of such a structure is ten years, the actual per bushel cost of storage is one cent and .52 cent respectively. Of course, these figures do not take into account interest charges on the investment.

Fitch[1] states that the first cost of storage in an average grade potato cellar is about 20 cents per hundredweight, or 1.2 cents per bushel on a ten-year basis. He further intimates that this cost can be reduced to 7 instead of 20 cents per hundredweight if little

Fig. 130.—Exterior front view of a Maine type of storage house. This particular house is an exception to the general rule in that it is provided with a roof ventilator.

regard is given to the permanence of the structure and farm labor is utilized in its construction.

Minnesota.—Henry Schroeder, of Sabin, Minnesota, submitted the following figures concerning his storage cellar shown in figure 126. This house is constructed with wooden walls, and a water-tight roof. The walls are four and a half feet below the surface of the ground and extend four feet above it. Its dimensions are 20 by 100 feet and it has an approximate storage capacity of 10,666 bushels, if figured on the basis of its full capacity of eight feet in depth. It was constructed at a cost of $1,200, or an average initial cost of 11.25 cents per bushel, or 1.125 cents on a ten-year basis.

Maine.—C. C. King, of Caribou, Maine, submitted the following estimates on a Maine type of storage house, 40 by 60 feet, having a storage capacity of 4,250 to 5,500 bushels, the cost of which he places at $3,500. The initial cost of storage in this case is 64 to 82 cents per bushel. The longer life of such a structure tends to reduce the average cost of storage over a period of years. King further states that the same house could be built without a concrete cellar, but resting on concrete piers, for about $2,500 to $2,700. According to King, the most common size of storage house in Aroostook County, Maine, is the 35 by 60 feet or the 40 by 50 feet.

FIG. 131.—Exterior rear view of same house showing driveway entrance located in side of building at the rear end.

George E. Howard, of Dover, Maine, says, "I am satisfied that the ordinary potato storage house, when built 40 by 60 feet with posts 16 feet or more, can be erected today for five and a half cents per cubic foot of contents, (approximately $2,100), figured from the bottom of the sills to the top of the plate. To this must be added the cost of the basement below the sills. If concrete, it will cost from $5 to $7 per cubic yard of concrete, depending upon the convenience of sand and gravel." He further says, "We have one near here 30 by 40 feet with 12-foot posts and 8-foot basement, 4 feet of which is below the level of the ground, which cost, including basement, $1,400."

It is evident from the foregoing figures that the Maine type of potato storage house is a much more expensive one than that of the dugout or cellar type. But if its durability is considered as well as the storage room provided in the superstructure, the ultimate cost of storage is not so very much greater.

The above figures are pre-war estimates.

Idaho.—In the fall of 1914, the Department of Agriculture built a potato storage cellar at Jerome, Idaho, in which some new

Fig. 132.—The more common type of the better class of Maine potato storage houses, with rear end driveway.

features of interior construction were embodied. The structure is 30 by 50 feet in dimensions with a central driveway. The side and end walls are of concrete, eight inches in thickness with 12-inch footings, and eight feet in height. The even span roof is of wooden frame construction, covered in the usual way with woven wire, straw and earth.

The interior arrangement of this cellar differs from that of any other noted in that it is provided with examination and disinfecting rooms, at one end of the cellar each approximately 10 by 10 feet in diameter. The balance of the cellar is divided into eight bins, four on either side of the driveway, each 10 by 10 feet. The wooden floor of these bins is a removable one, being constructed in three sections, each of which consists of 3-inch strips of board nailed to cleats, with 1-inch space between the strips. These floor sections are supported by 2 by 6 inch joists which, in turn, rest on three 4 by 6 sills. The 2 by 6 joists were given an inch shoulder on the supporting sills, thus providing a 5-inch opening into the driveway, as the joists are at right angles to it (Fig. 109). The interior face of the concrete side and end wall of the storage cellar

FIG. 133.—Potato storage house erected by the U. S. Dept. of Agriculture on Aroostook Farm, Presque Isle, Me. Note large roof ventilators or cupolas. Small greenhouse on left is used for starting the seed potatoes.

proper is furred with 2 by 4 studding, spiked to the 4 by 6 sill below and to the rafters above. The studding is spaced 32 inches apart in the clear and is covered to the height of six feet, with 4-inch boards spaced one inch apart. The slatted division walls of each bin are double when in place. They are constructed in sections similar to the floor, and are attached at each end to supporting posts. The cleats on which the 4-inch board slats are nailed come opposite to each other when in place, thus insuring a 2-inch air space in the walls. This type of floor, wall, and partition construction affords a complete circulation of air around each bin, which is especially desirable for the storage of seed stock.

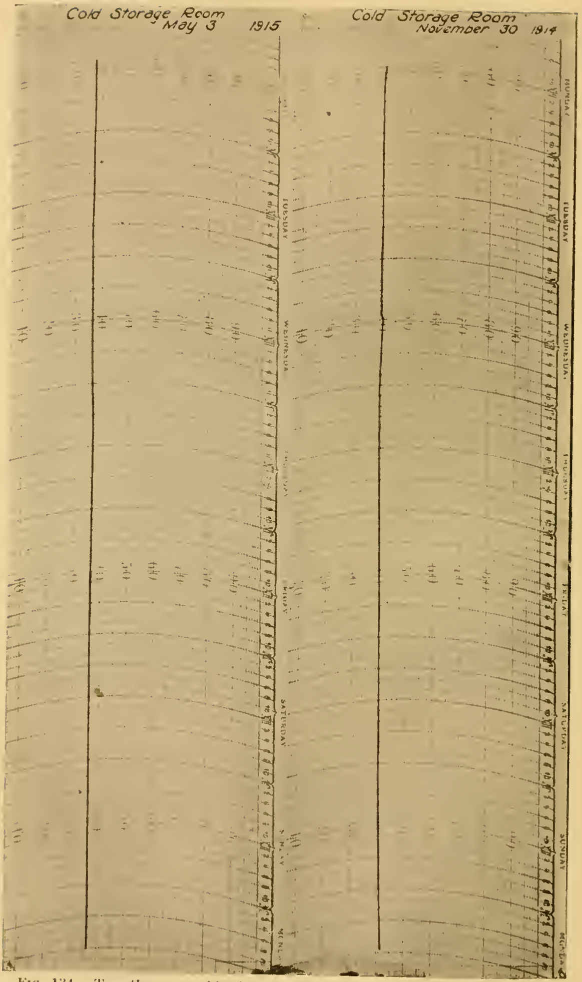

FIG. 134.—Two thermographic sheets showing temperature record in storage room cooled by the brine system of refrigeration during the weeks ending Nov. 3, 1914 and May 3, 1915 respectively. Note uniformity of temperature.

QUESTIONS ON THE TEXT

1. What is the most primitive type of storage?
2. Describe the method of pitting potatoes.
3. What is a safe limit in size?
4. What should be the shape of the pile?
5. Why should there be some provision made for ventilation?
6. Give successive steps in the pitting of potatoes.
7. What is the advantage of the pitting system? The disadvantage?
8. What factors govern the determination of the right type of a storage house?
9. Where is the dugout or cellar type of storage house most commonly employed?
10. What are the chief things to consider in the location of such a storage house?
11. Describe the construction of the house, *viz.*, the cellar, walls, and roof.
12. What further suggestions are given regarding more expensive and durable walls?
13. What modification in roof structure is necessary in the humid sections of the north central and eastern states?
14. What function besides insulation does the straw covered roof perform?
15. What provision should be made to exclude either heat or cold from the entrance way?
16. How is ventilation usually provided in the storage house?
17. Describe interior arrangement of house.
18. Describe a ventilated bin.
19. Where no provision is made for a driveway into the storage house how are the potatoes put into it?
20. Describe the insulated wooden storage house. Where is it usually found?
21. Why is the type of storage house now advocated for sweet potatoes not satisfactory for Irish potatoes?
22. In what way does the Aroostook, Maine, type of potato storage house differ from those previously discussed?
23. How is this type of house usually constructed? Give sizes.
24. How are the basement bins usually filled?
25. Of what use is the wooden superstructure?
26. To what extent is artificial refrigeration employed in the potato storage house?
27. What advantage has it over ordinary storage? Where most apparent?
28. What are the present storage facilities in the South?
29. Describe the "Cooper brine circulation system?"
30. Is the Cooper system a satisfactory one? Give arguments for and against.
31. What is the usual method of determining the storage capacity of a given basement or bin space?
32. Give the cost data on the construction of the cellar type of storage house?
33. Does the above cost estimate represent the present sum necessary to construct such a house? How would it differ?
34. Give Fitch's cost estimate on an average grade potato cellar?
35. What was Schroeder's estimate of cost of constructing a 20 by 100 feet storage house in the Red River Valley?

36. How do King's and Howard's estimates on the Maine type of storage house compare with those of the preceding ones?
37. What new features were introduced in the interior arrangement and bin construction of the Jerome, Idaho, potato storage house?

QUESTIONS SUGGESTED BY THE TEXT

1. Make an estimate of the number of local storage houses of each of the five types.
2. Describe some of these which you have seen.
3. Visit a cold storage plant in your section. Study its advantages and disadvantages for potato storage.
4. If space is rented in this house, calculate the cost per bushel for storage.
5. Make an estimate for constructing a house, locally, of one of the types 2, 3 or 4.

References Cited

1. Fitch, C. L. 1910. Productiveness and degeneracy of the Irish potato. *Col. Sta. Bul.* 176: 47, Nov., 1910.
2. Thompson, H. C. Storing and marketing sweet potatoes. *U. S. Dept. Agr. Farmers' Bul.* 548: 1-15.

CHAPTER XV

POTATO DISEASES AND THEIR CONTROL

THE potato, like most other agricultural plants, has its parasites which prey upon its aërial and subterranean parts, causing more or less severe injury to the plant itself and to its resultant tubers. There are also a number of obscure maladies affecting the potato plant which as yet cannot with certainty be classed as parasitic diseases, or for that matter, even as diseases in the strict sense of the word. These types of potato troubles have, for the lack of a better understanding of them, by the pathologists, been designated as physiological troubles. There is, however, a growing feeling in the minds of some of the leading pathologists and potato specialists that some of these maladies will in the end be found to be due to parasitic organisms.

Losses Due to Diseases.—It is impossible to estimate with any degree of accuracy the annual losses sustained by the potato growers of this and other countries from diseases and physiological troubles affecting the potato plant. It has been estimated that the potato growers of New York State in 1903 sustained a loss of nearly $10,000,000 from the late blight alone[18]. Losses of $100,000,000 are by no means infrequent, and it may be assumed that, if all the facts were known, it would show a much larger loss than the amount mentioned. These figures are sufficient to emphasize the great economic importance of these diseases, insofar as they reduce the money value of the potato crop of the country.

DISEASE CLASSIFICATION.—The following classification of diseases according to causes with preventive measures and remedies is submitted in the hope that it will afford a convenient and ready reference to the more important diseases of the potato.

Parasitic Diseases

	Remedial and Preventive Measures.
Fungous.	
1. Early blight 2. Late blight	Spraying plants with Bordeaux mixture for 1 and 2. Use of disease-free seed (2).

3. Fusarium wilt 4. Fusarium dry rot (a) *F. eumartii* (b) *F. radicicola* (c) *F. oxysporum* (d) *F. hyperoxysporum* (e) *F. discolor* var. *sulphureum* (f) *F. trichothecioides* 5. Verticillium wilt	Use of disease-free seed. Soil sanitation:—rotation of crops and use of disease-free land where possible. Remove all wilt infected plants (3) and (5). Careful handling of tubers. Disinfection of storage house and low storage temperature, 34° to 36° F. in case of 4 (f).
6. Rhizoctonia 7. Common scab	Treatment of seed in corrosive sublimate or formalin solutions, preferably the former. Use of clean seed; soil sanitation:—rotation, etc.
8. Silver scurf 9. Wart 10. Leak	Use disease-free seed. Plant immune varieties in case of (9). Reduction of mechanical injuries of tubers and rejection of all injured stock in shipments in case of (10).
Bacterial.	
11. Blackleg	Treatment of seed in corrosive sublimate or formalin solutions. Use disease-free seed. Remove infected plants and tubers.
12. Soft rots 13. Bacterial wilt 14. Streak	Use disease-free seed. Soil sanitation:—rotation, etc. Remove infected plants.
Ultra-microscopic organisms, or a virus.	
15. Mosaic 16. Leaf-roll	Use disease-free seed. Control insect pests. Remove all diseased plants.
Slime mold.	
17. Powdery scab	Treatment of seed in corrosive sublimate solution. Plant clean seed stock. Soil sanitation.

Non-parasitic Diseases

18. Spindling sprout 19. Net necrosis 20. Curly dwarf 21. Tip-burn 22. Arsenical injury	Use strong vigorous seed stock. Rogue out all affected plants for 18 and 20. Conserve soil moisture. Spray thoroughly with Bordeaux mixture. Use lime in arsenical solutions used for insect control.

Parasitic diseases are those which are capable of invading healthy and normally protected plant or animal tissues. The non-parasitic types of troubles are those which are incapable of invading healthy and normally protected plant or animal tissues.

Early Blight.—The early blight is caused by a fungus, scientifically known as *Macrosporium solani*. The attacks of this disease are wholly confined to the foliage of the potato plant. In the New England States, the disease usually makes its appearance on the plants at a much earlier date than in the Middle West.

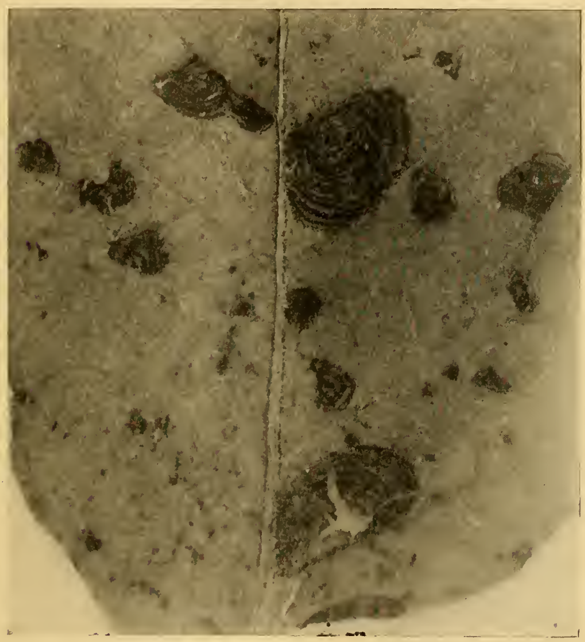

Fig. 135.—Potato leaf showing advanced stage of early blight infection

The economic importance of the early blight, as judged by the damage it does to the potato crop, is very considerable. The writer has observed a field in Franklin County, Vermont, that was almost completely destroyed by early blight in the latter part of July. A very conservative estimate of the reduction in yield from this field could not have placed it at less than 50 per cent. Jones[6] asserts that the losses incurred from early blight in Wisconsin may amount to from 10 to 25 per cent; while Coons[2] is of the opinion that the losses sustained from this disease in Michigan may average about 25 per cent. It is evident from the foregoing statements that when there is a serious early blight epidemic the losses sustained are, as a rule, much greater than the average potato grower realizes.

Symptoms.—The outward or external evidences of the presence of early blight on potato leaves is first noted as a dark brownish or blackish spot of oval, angular or irregular shape which, as it develops, begins to show a series of concentric rings which give it a rather characteristic appearance (Fig. 135). When the infection is severe, these spots enlarge and finally coalesce with each other to form larger and still larger areas until finally the entire surface of the leaf may become infected and eventually wilts, dies, and drops off.

How Infected.—The method of infection, according to Jones,[6a] may be either through the stomates or directly through the cuticle. Rands[16] states that "in central Wisconsin, natural infection is generally first visible from June 20 to July 10 on the crop planted April 25 to May 15, and on the late crop, spots may be observed from the middle of August on, depending upon three factors: age, vigor of plant, and weather conditions."

Source of Infection.—It is thought by Rands (*l.c.*) that the source of infection of the early crop is from the over-wintered spores, and possibly from conidia produced by over-wintered mycelium.

Preventive Measures and Results.—The only satisfactory preventive measure thus far known is that of keeping the plants thoroughly sprayed with Bordeaux mixture. Lutman,[8] in a summary of 19 years of spraying, makes the following statement regarding the fungicidal value of Bordeaux mixture when properly made and applied: "It very efficiently protects plants from the attacks of the early and the late blight." Milward[11] found that the early blight could be satisfactorily controlled by four or more applications of the Bordeaux mixture, provided the first one was made not later than August 15. Jack[5] furnishes additional evidence of the possibility of controlling early blight with Bordeaux mixture. Spraying experiments over several years showed annual increases in yields of the sprayed plants over the unsprayed of from 16 to 57 per cent. Rands (*l.c.* pp. 42-44) says, "For the early crop under Wisconsin conditions, the disease can be profitably controlled by

4 to 6 applications of the standard 5-5-50 Bordeaux mixture. Complete control can only be attained by weekly sprayings, begun when the plants are 6 to 8 inches high and continued throughout the remaining period of growth.

"For the late crop, the results indicate that 3 or 4 applications ordinarily recommended for the control of late blight will also control early blight.

"Thoroughness of application cannot be over-emphasized in spraying for early blight."

Further details concerning the early blight may be secured by consulting the references mentioned in this discussion, and also those listed in the bibliography appended to this chapter.

LATE BLIGHT

The disease of the potato, commonly known as late blight *(Phytophthora infestans)*, is by far the most destructive foliage disease affecting the potato crop. In certain seasons it is also the most destructive tuber disease.

Occurrence and Distribution of the Disease.—As a rule, the late blight is confined very largely to the North temperate zone, including the whole northeastern portion of the United States and Canada. It is also fairly prevalent in the Pacific Coast sections of the states of Washington and Oregon. It also occurs, though hardly in epidemic form, along the whole Atlantic coastal plain section, but as a rule causes little injury south of Maryland, as the early crop of this region is usually harvested before the late blight has much opportunity to seriously infect either foliage or tubers. The late crop of this section is rarely attacked by the fungus because the climatic conditions are unfavorable to its development. Late blight epidemics are more frequent in the Canadian Provinces of Quebec, New Brunswick, Nova Scotia, Prince Edward Island, the New England States, New York, and certain portions of Pennsylvania, than in any other portion of North America. It is also a serious menace to the potato crop in northern Europe, including the British Isles, where epidemics are of as frequent occurrence as in North America. The Australian potato grower also has to contend with the late blight. According to Merino,[10] the potato crop of Peru suffered from an especially severe epidemic of late blight during the years 1867 to 1877.

It is evident, from the foregoing brief resumé, that the late blight is prevalent in practically all potato-growing sections where cool and fairly moist climatic conditions prevail during the latter portion of the growing period.

Early History of the Disease.—It is probable that late blight occurred in the potato fields of Peru, Chili, Bolivia, and other countries in the western portion of South America, where the potato was undoubtedly grown, long prior to its introduction into Europe. In fact, the inference is a fair one that the late blight was introduced into Europe from South America by means of infected tubers. Two disastrous potato failures, due to late blight in Europe, are mentioned by Cathcart (*l.c.* pp. 276, 277); the first in 1795 and the second in 1845-46. The latter epidemic is known to have begun in 1840 and reached its climax in 1845-46.

Fig. 136.—Potato stem and foliage affected by the Late Blight. Maine Sta.

Life History of Late Blight.—The life history of the late blight fungus has been a source of considerable controversy among scientists with respect to the manner in which it is carried over from one year to another. Melhus[9] states that at least six theories have been advanced at various times regarding the yearly advent of the disease, *viz.*: "(1) That the mycelium lives over in the soil; (2) that the mycelium is perennial in the diseased tuber; (3) that resting spores are produced which function in renewing infection; (4) that the mycelium is latent in the potato plant; (5) that the fungus fruits on the parent tuber in the soil, and the spores reach the surface and cause infection of the foliage; and (6) that sclerotia-like bodies or muco-plasm give rise to infection." Melhus further states that the second theory is the only one supported by any amount of experimental data.

Assuming that the perennial mycelium theory is correct, the life history of the fungus is a comparatively simple one. The mycelium or the plant structure proper of the late blight overwinters or hibernates in the infected tubers. Melhus says (*l.c.* p. 99) that, when infected tubers are used for seed purposes, "the mycelium grows from the seed piece into the stem, where it travels up to the surface of the soil and sporulates." If the weather conditions are favorable to the germination of the spores, infection of the foliage (Fig. 136) is almost inevitable; and with continued favorable weather an epidemic may develop. The spores formed are usually known to laymen as summer spores; the pathologist calls them conidiospores. These reproductive bodies are formed on the extreme tips of branched hyphæ, or fruit-bearing structures, which protrude through the epidermis of the under side of the infected portions of the leaf (Fig. 137). As each successive spore is fully matured, it is separated from the fruit-bearing stalk. When the moisture and temperature conditions are favorable for the growth of the late blight, the hyphæ and resultant conidiospores are borne in such great abundance as to give the infected areas the appearance of being covered with a whitish, glistening, felt-like growth. When such conditions of growth obtain, the spread of the disease is very rapid. As each spore is cut off from its fruiting hypha, it drops upon the foliage beneath; or it may be borne by currents of air to adjacent plants and, finding lodgement upon the upper surface of a healthy leaf it will, if sufficient moisture is present, germinate in from two to four hours. The process of germination is an interesting one, the tip of the spore opens and six or more small bodies called zoöspores are thrust out. These bodies are naked masses of protoplasm provided

FIG. 137.—Characteristic appearance of Late Blight infection of potato leaves. Maine Sta.

with whip-like strands, or as they are technically known, cilia, by means of which they move about in the drop of water for a short time, after which they come to rest and push out a slender germ-tube, which penetrates the epidermal structure proper in some cases, while in others the germ-tube passes through the stomata. Once the germ-tube has penetrated the leaf structure, it develops rapidly into a mycelium structure, which in from two to four days produces fruiting hyphæ.

The tubers are infected (Fig. 138) by the fallen spores, which are carried through the soil by the aid of rain. Late blight in

Fig. 138.—Tubers affected with Late Blight rot.

the absence of other infection causes a dry rot of the tuber. The soft rot malodorous decay of the tuber, following late blight infection, is due to non-parasitic bacteria which invade the dead tissues caused by the blight and rapidly complete the destruction of the tuber.

Control Measures.—It is obvious that if the primary infection each season is due to planting blight-infected seed pieces, the first control measure to be taken is the rejection or exclusion of all infected seed stock, insofar as it is humanly possible to do so. The second control measure is that of protecting the foliage of plants from late blight infection by keeping them well covered with

Bordeaux mixture; this generally necessitates spraying the plants from three to six or more times during the growing season. The number of sprayings is, in a large measure, dependent upon seasonal conditions; if the weather is favorable to the development and spread of late blight, that is, rainy or muggy, and the temperature not excessively high, more frequent sprayings are necessary to prevent infection than when the weather is dry and hot as, under the latter conditions, the late blight is quickly checked. It should be borne in mind that under favorable conditions for the growth and spread of late blight, it can only be held in check by the most thorough and careful spraying. It is not sufficient to simply go over the field with a sprayer carrying a pressure of 75 to 100 pounds per square inch and one nozzle to the row, applying possibly 50 to 60 gallons per acre. Such spraying will not control late blight, and is responsible for many criticisms of the efficacy of Bordeaux mixture in the prevention of late blight.

The grower should also bear in mind that no amount of spraying will save the infected portions of the plant after the fungus has once entered its tissues. The Bordeaux mixture, or any other fungicide, is a preventive and not a remedy for blight. To successfully combat this disease, it is necessary that the foliage of the potato plant be kept thoroughly covered with Bordeaux mixture throughout the period in which infection is most likely to occur; but inasmuch as this period is a variable one, depending on climatic conditions, it is advisable to make the first application when the plants are from six to eight inches in height. The application should be repeated as often as may be necessary to keep the new growth, as well as the old, thoroughly covered with the fungicide.

In the purchase of a spray machine, it is important to bear in mind the following factors: (a) The durability of the machine; all working parts of the pump coming into contact with the spray liquid should be made of brass; (b) that the pump should be capable of developing and maintaining a pressure of from 150 to 250 pounds when carrying two or three nozzles per row; (c) that the construction of the pump, especially of the piston chambers, be such as to require a minimum amount of packing, and that all valves or chambers requiring packing shall be easily accessible and of simple construction. For further information on sprayers see Chapter XVII.

FUSARIUM WILT

Symptoms of Disease.—The first noticeable symptom of fusarium wilt in the potato plant is a characteristic rolling or wilting of the lower leaves, followed in severe cases by premature death of the foliage and finally of the whole plant.

The date at which the above symptom first manifests the presence of the disease in the plant varies according to the date of infection. If disease infected tubers are planted, it may be evidenced in an imperfect stand of uneven-sized plants. Generally speaking, wilting of the foliage does not occur until the plants are a foot or more in height. The wilting is due to the invasion of the ducts or water channels, through which the leaves are supplied with moisture, by the mycelium of the fungus which finally causes a complete stoppage of the upward movement of water, thereby resulting in the death of the plant.

In the earlier stages of the disease, the lower leaves are first to wilt. This wilting and consequent rolling of the leaves should not be confused with the true leaf-roll. The first symptom of fusarium wilt differs from the true leaf-roll, in that the wilted leaves lack turgidity, whereas those affected with leaf-roll are turgid to the point of brittleness.

The foliage of wilt infected plants assumes a lighter green color than that of normal plants and as the disease progresses may, and generally does, turn quite yellow.

Causal Organism.—The causal organism is, as has already been stated, a fungus known as *Fusarium oxysporum*. There are two sources of infection of the plant from this disease: (a) From planting infected tubers, and (b) from fusarium-infected soil. The fungus gains access to the main stem of the plant through its rootlets, and, possibly in the case of infected seed pieces, through direct invasion of the main stem.

Occurrence of the Disease.—The occurrence of fusarium wilt seems to be regional rather than general. It is prevalent in the Red River valley of Minnesota, North Dakota, Nebraska, Utah, Arizona, California, New York, and the New England States. It is, however, more or less generally prevalent from New York, west to the Pacific coast, and is generally distributed throughout Europe.

Control Measures.—As diseased seed and infected soil are the two sources of infection, its control is confined to the use of disease-free seed and of land which is free or reasonably so from the fusarium wilt fungus. The first control measure is easier of execution than the second one, as the presence of the disease in the seed tuber can usually be detected, but there is no practical way of determining whether the fungus is present in the soil or not, except through a previous knowledge of the behavior of a potato crop on that particular soil or field; and there is, as yet, no practical method of disinfecting the soil.

Fusarium-infected tubers, at least those in which the disease has made some progress, show a brownish discoloration of the vascular bundles at the stem end. This discoloration is only detected by clipping off a thin slice from the stem end of the tuber. It is well to state, however, that not all tubers showing a brownish discoloration are necessarily infected with fusarium wilt, as there is an internal browning thought to be physiological which very closely resembles the wilt disease. Inasmuch, however, as all ring discoloration of the tuber, other than that which is normal to the variety, is undesirable, it is advisable to reject all such tubers for seed purposes. All plants showing infection in the field should be removed if the crop is intended for seed purposes. Careful roguing in the field is, perhaps, more important than the examination of each seed tuber in the manner just described.

FUSARIUM DRY ROT

Dry rot of potato may be caused by one or more of several species of Fusaria which are known to be parasitic on the tubers of potatoes.

Forms of Dry Rot.—There are a number of forms of dry rot such as, the dry stem-end rot, the powdery dry rot, and a number of other forms which are largely due to wound invasions by the fungi.

Species of Fusarium.—Carpenter[1] claims that *F. eumartii, F. radicicola, F. oxysporum, F. hyperoxysporum* and *F. discolor* var. *sulphureum* have been clearly proven to be parasitic upon the potato tuber. In addition to these, it is known that *F. trichothecioides* is responsible for heavy tuber losses, due to the "powdery dry rot," in western Nebraska and other western states where the conditions are favorable for its development. According to Carpenter, (*l.c.* p. 207), *F. eumartii* is a new stem-end and wound-

Fig. 139.—Jelly-end rot of the potato tuber.

invading dry rot of the potato tuber which annually causes serious damage in Pennsylvania. *F. radicicola* is a widely prevalent dry rot similar to *F. eumartii.* It is also responsible for the so-called "jelly-end" rot of the tuber so common in the tule lands of San

FIG. 140.—Potato plant affected with Verticillium Wilt.

Joaquin and Sacramento River delta regions in California (Fig. 139), as well as other irrigated sections in the Pacific northwest. It is commonly associated with *F. oxysporum* in this disease. *F. oxysporum* and *F. hyperoxysporum,* which have been commonly regarded as purely vascular tissue parasites, have been found by Carpenter to be capable of entirely destroying potato tubers. *F. discolor,* var. *sulphureum* occurs in hollow-hearted potatoes, causing decay. The infected portion of the tuber turns a sulfur yellow. According to Carpenter, it has been isolated from decaying tubers from both North and South Dakota.

Preventive Measures.—Employ the same preventive measures as were recommended for the control of fusarium wilt. Care in the harvesting and handling of the crop throughout the harvesting, sacking and shipment of it to market is necessary to the end that mechanical injuries to the tubers may be reduced to the least pos-

FIG. 141.—Plants in foreground affected with Verticillium Wilt. Near Portland, Ore.

sible percentage. The importance of observing these precautions can only be realized when we remember that most of the tuber decay caused by these species is due to the invasion of the fungi through bruised or cut tissues. It has been very clearly demonstrated that in the case of the powdery rot caused by *F. trichotheciodes,* practically all of the infection is the result of wound infections by this organism. It has also been clearly shown that thorough disinfection of the storage house, by spraying or washing all interior parts with a corrosive sublimate solution or fumigating the house with sulfur fumes, is absolutely necessary before storing the new crop. Fortunately, careful studies have shown that this fungus can be held in check by holding the temperature of the storage house at about 35 to 40 degrees F.

VERTICILLIUM WILT

Symptoms.—The outward symptoms of verticillium wilt, (*V. albo-atrum*), insofar as they are expressed by the affected plants, are very similar to those of fusarium wilt (Figs. 140 to 142).

Fig. 142.—View shows condition of plants in a low part of the field; many dead and wilting plants. Same field as above.

Orton[14] says: "Verticillium wilt is often not strikingly different from fusarium wilt in outward appearance, though it may induce a more rapid wilting. The presence of the mycelium and vascular browning in the upper portions of the plant is indicative of verticillium, as fusarium does not usually extend into the tips of the stalks. The profuse production of conidia on the stalks, often before they are entirely dead, is still more characteristic." It is not as prevalent in the United States as in Europe, though in neither country does it cause as serious injury to the potato crop as does the fusarium wilt. Unlike the latter, it seems to thrive best in the northern potato-growing regions.

Preventive Measures.—The most effective method of controlling the disease is that of seed selection. Disease infected tubers show a darker discoloration of the vascular ring than do those infected with fusarium wilt. Rotation of crops should also be practised.

RHIZOCTONIA SOLANI OR BLACK SCURF

Economic Importance.—The disease of the potato, botanically known as *Rhizoctonia solani*, is of vastly greater economic importance than is generally recognized by potato growers of this and foreign countries. This is partly due to the fact that a considerable portion of the injury caused by this disease is not observed, because the portion of the potato plant attacked is beneath the surface of the ground. To a large extent this unobserved injury and consequent loss in crop production is sustained in the first stages of growth of the potato plant. The extent of the loss is dependent on the degree of infection of the soil, or that of the seed piece planted. The character of this loss is in the infection and complete destruction of the germinating sprouts of the seed piece planted, resulting in missing plants which the grower usually attributes to mechanical defects in the operation of the potato planter used, or to the lack of a strong eye in the seed piece itself. This statement is amply confirmed in Figures 143 and 144, which well illustrate the manner and character of the injury inflicted by this fungus.

FIG. 143.—Typical example of Rhizoctonia injury. Note dead shoots at base. Maine Sta.

Symptoms and Causal Organism.—The very serious fungous disease of the potato plant, *Rhizoctonia solani*, is quite commonly known as *black scurf* or *scurf*. This name has been applied to it as a result of the appearance of the resting or sclerotial stage of this fungus on the surface of the tuber. The sclerotial bodies of the fungus resemble a dark brownish or blackish felt-like mass which, in general appearance, is not unlike small masses of soil clinging to the skin of the tuber (Fig. 145). These masses are not removed by washing but may be scraped off without leaving any visible injury to the skin of the tuber. These sclerotial bodies are the resting stage of the fungus, and are a direct means of transmitting the fungus to the resultant crop, if the infected tubers are not treated in a corrosive sublimate solution before planting them. During the stage at which the fungus is producing its perfect spores, it is known as *Corticium vagum* var. *solani*. This stage in the development of the fungus usually occurs about the middle of the growing season (Figs. 146 and 147).

Fig. 144.—Typical example of Rhizoctonia injury to tuber-bearing stolons. Maine Station.

Method of Attack.—The fungus attacks all underground parts of the plant. The chief points of difference between this fungus and that of the fusarium wilt is that the former attacks the outer portions of the roots, tuber-bearing stolons and the main stem of the plant beneath the surface of the ground, and in a large number of instances completely girdles them. The chief injury comes from the destruction of the germinating shoots, and the tuber-bearing stolons. These injuries are direct and appreciable, whereas the losses caused by the destruction of the smaller rootlets or partial encircling of the main stem are difficult to estimate. When it causes severe injury to the main stem of the plant it is usually evidenced in a more erect and rigid condition of the terminal portion of the stem, the upper leaves of which show a more or less distinct reddish tinge; and in the formation of an abnormally large number of relatively small tubers on the stem, just at or beneath the surface of the ground.

Preventive Measures.—Disinfection of the seed by immersion in a corrosive sublimate solution of the same strength and for the same period as that recommended for common scab. Planting on clean land, when it is possible to do so, is also advisable.

COMMON SCAB

Causal Organism.—The common scab of the potato tuber is caused by an organism, *Actinomyces scabies*, which has perhaps

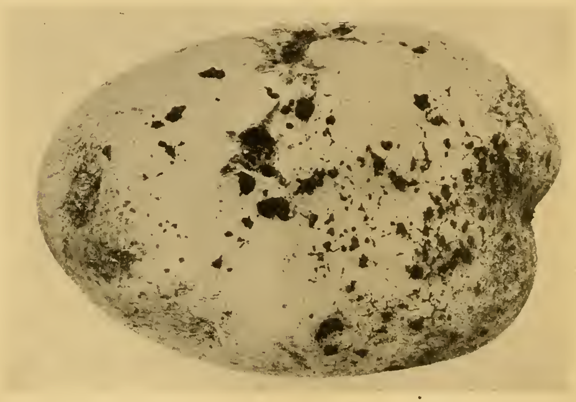

FIG. 145.—Tuber showing sclerotial or resting stage of Rhizoctonia. If such a tuber was used for seed purpose without being immersed in a corrosive sublimate solution for 1½ to 2 hrs. it would infect the resultant crop.

occasioned greater controversy, as to whether it should be classed with fungi or with bacteria, than that of any other parasitic disease. The latest classification places it in the fungi group of plants. Unlike most other fungous or bacterial diseases attacking the potato, the common scab injury is very largely confined to the tuber and unless the scab injury is severe, there is no appreciable reduction in yield.

Tuber Injury.—The chief injuries are: (1) The appearance of the tubers; (2) the slightly greater waste in preparing them for table use; (3) the reduced yield; (4) a very direct monetary loss involved due to the discrimination of the markets against scabby tubers; (5) their unsalability for seed purposes; (6) if used for seed purposes, there are likely to be a great many missing plants

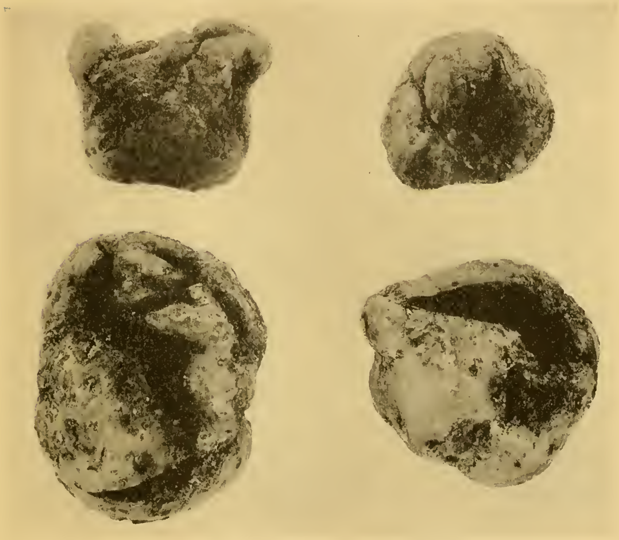

Fig. 146.—Extreme example of tuber injury by Rhizoctonia. Maine Station.

owing to the weakening or destruction of the germs or buds of scab-infected eyes (Figs. 148 and 149).

Distribution.—Common scab is, perhaps, more widely distributed than any other disease of the Irish potato. Investigations by Pratt[15] have shown that scab organisms may be present in absolutely virgin soil rather far removed from that under cultivation. In fact, so common is this disease that it may be said to occur almost everywhere the potato is grown.

Remedial Measures.—As the scab organism can and does live over in the scab pustules on the tuber from one season to the next, and under favorable conditions is able to infect the new crop of tubers while they are still growing, it is advisable to disinfect all seed stock used regardless of whether it is scabby or not. This is readily accomplished by immersing the tubers, before they are cut, in a solution of corrosive sublimate or of formalin.

The corrosive sublimate solution is a more effective disinfecting agent for the black scurf (rhizoctonia) than is the formalin.

When the soil in which the seed is to be planted is already infected with the scab organism, seed disinfection is not necessarily a guarantee of a disease-free crop of tubers.

Preventive Measures.—The only preventive measure possible for the individual grower to put into practice is that of adopting

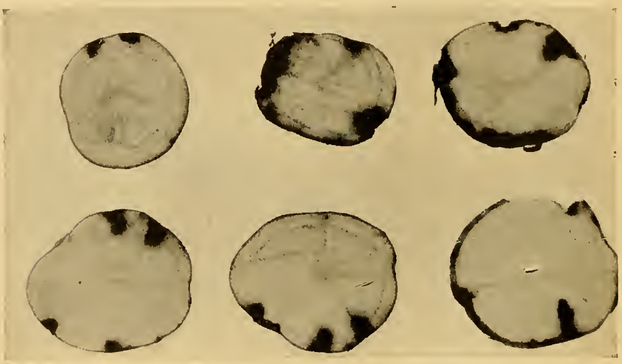

Fig. 147.—Cross sections of tubers affected with Rhizoctonia Maine Station.

a definite system of crop rotation and in avoiding, as far as possible, the use of land known to be infected with the scab organism for potatoes. In view of the fact that virgin soil may be infected with the scab organism, the use of new land does not offer an absolute guarantee of freedom from infection, though as a rule it does produce clean seed. Thus far, no practical method has been discovered for destroying scab organisms in the soil. It is known, however, that a soil giving an alkaline reaction is much more likely to be infected with scab than one that is slightly acid. Application of lime to soil intended for growing potatoes is not, therefore, recommended unless it is known that the soil is too acid to permit of the development of a satisfactory crop, or that it is known to be free from scab infection. Scab infection may be controlled to some extent by turning under green rye, clover, alfalfa, or other suitable green manuring crops, as the acidity in the vegetable matter turned under tends to make a slightly alkaline soil neutral or even slightly acid. Heavy applications of fresh horse manure in the spring before planting the crop seems to aggravate the scab

FIG. 148.—Stem roots and tubers showing common scab infection. Maine Station.

when it is already in the soil. This is due to the fact that the manure furnishes an excellent growing media for the potato scab organism.

SILVER SCURF

It is supposed that the silver scurf disease, *Spondylocladium atrovirens,* is of recent introduction from Europe, but it is rather doubtful if this supposition is correct, as the rather common interchange of varieties between this country and Great Britain in former years must have resulted in the introduction of most of the less easily recognized diseases affecting the potato tuber. Fortunately, the disease known as silver scurf is not a very serious pest as compared with many others.

Description.—Tubers infected with silver scurf first develop dark spots or areas on the surface of the tuber. These areas soon begin to show the fruiting or spore-bearing hyphæ, which appear to the unaided eye as dark points or protrusions. Under favorable

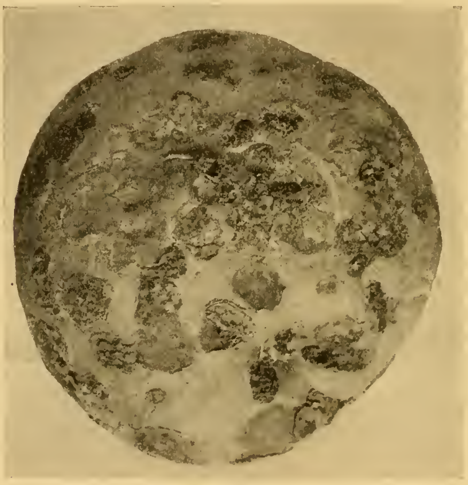

Fig. 149.—Tuber badly disfigured with common scab.

conditions, such as heat and moisture in the storage bin, the newly developed spores may cause fresh infections. The fungus seems to injure the skin, and possibly the cells beneath, to a sufficient extent to cause a more rapid loss of moisture, resulting in slightly sunken areas. The skin loses its normal color and takes on a silvery cast, thus giving to the fungus the name of silver scurf.

Preventive Measures.—Seed treatment appears to be ineffective, hence the only preventive measure possible is that of the use of disease-free seed.

POTATO WART DISEASE

The occurrence of this disease, *Chrysophlyctis endobiotica,* was first noted in North America, in October 1909, by Gussow,[3] the Dominion botanist of Canada, who recognized its presence on some specimens of tubers sent to him for identification from a locality in Newfoundland. Its occurrence in the United States was first recognized by Professor J. G. Sanders, of the Pennsylvania Department of Agriculture, at Harrisburg, to whom infected tubers were sent from Highland, Pennsylvania, in September 1918.[7] A careful survey of this region, immediately after the recognition of its presence, resulted in finding it in twenty-six towns and villages in lower Luzerne County. It now seems probable that the disease was introduced into this mining section of Pennsylvania through the importation from Europe of twelve carloads of German grown potatoes in 1912. More recently it has been found in some mining towns in West Virginia and Maryland. It was originally described in Hungary in 1896.

Description.—The wart disease of the potato is caused by one of the lower orders of fungi. It attacks all underground portions of the plant, but more especially the tubers. Infection of the tubers is usually through the eye. The first visible symptoms of infection are the presence of tiny wart-like growths, which rapidly enlarge in size until, in severe cases, the tuber is literally converted into a huge mass of warty excrescences, which bear little, if any, resemblance to a potato. In such instances, and even where infection is less severe, the tuber is valueless for table purposes. The parasite reproduces itself by means of minute, yellow-covered, globular bodies called sporangia. These sporangia are born in great numbers just beneath the surface of the wart. The summer sporangium is surrounded by a thin wall, while that of the resting or winter sporangium is quite thick. The former germinate as soon as mature, and the spores produced thereby may infect other portions of the same plant. On the other hand, the resting sporangia may remain inactive for a long period, probably several years.

Each germinating sporangium releases a large number of microscopic, free-swimming spores which move about in the soil water. If these bodies fail to come in contact with developing potato tubers, or tender portions of the plant which they are capable of penetrating, they die.

Preventive Measures.—The only effective preventive measures known are those of planting disease-free seed on non-infected soil; growing other crops on wart-infected land; or the employment of disease-resistant varieties. Fortunately for the potato industry, in wart-infected districts there are a number of commercial varieties of potatoes that appear to be entirely immune to the disease. Investigations thus far have indicated that varieties of the Irish Cobbler group, and with one exception, thus far, of the Green Mountain group, are entirely immune to the wart disease. So is Spaulding No. 4 or Rose 4. In Great Britain, rather extensive studies upon the immunity of the leading commercial varieties to the wart disease have been carried on at Ormskirk, Lancashire, England, for the past two seasons, with the result that they are now able to recommend quite a respectable number of wart immune varieties.

LEAK

Causal Organism.—The disease of potatoes commonly known as leak is, according to Hawkins,[4] probably caused by *Pythium debaryanum.* In 61 attempts, Hawkins succeeded in isolating the fungus from leak infected tubers a total of 49 times. This fungus was also found to be rather universally present in soil samples taken from various parts of the delta region, in the vicinity of Stockton, California; and the application of such soil to mechanically injured potato tuber tissues caused infections, from which the organism, *P. debaryanum,* was isolated. No cases of infection, either in the field or laboratory, were observed when the skin of the tuber remained unbroken.

Action of the Disease on the Tuber.—The action of the organism on the tissues of the tuber, under favorable conditions, causes a rapid and practically complete breaking down of the cellular structure of the tuber, and the resultant loss of its liquid contents. For this reason, the disease has been given the name "leak," that is, the liquid contents leak out. In discussing the losses due to the disease in the delta region of the San Joaquin River, California, Hawkins says, "The rot is manifest in hot weather, and appears soon after harvesting. As the potatoes in this region are sacked in the field and practically all shipped immediately, the disease is, therefore, first evident in the car or warehouse. In extreme cases a whole shipment may be so badly damaged as to be worthless."

Preventive Measures.—As the disease is incapable of infecting uninjured tubers, the obvious preventive measure to be employed is that looking toward a reduction of cuts and bruises, resulting from the harvesting and handling of the crop. The universal practice of the potato growers of this section of breaking off the knobs or prongy growths, so common with the Burbank, is an undesirable one because it offers an entrance point for the fungus. As most of the digging is done by hand with heavy five- or six-tined hoe forks, many tubers are injured by being pierced with one or more of the prongs, thereby inoculating the tuber with disease. Such injured tubers should not be sacked as salable table stock, because the chances are strongly in favor of such tubers decaying in transit, and others may become infected from them. All cut, bruised or pierced tubers should, therefore, be discarded as they are being sacked for market.

BLACKLEG

The bacterial disease of the potato commonly known as blackleg, *Bacillus phytophthorus,* is rather widely distributed throughout the potato-growing sections of the northeastern United States and Canada. So far as known, the first recorded occurrence of this disease was made by Jones[6b] in Vermont, in 1906. It was noted in a field of Green Mountain potatoes on the Station farm. The seed used in planting this field had been purchased in Houlton, Maine.

Character and Appearance of the Disease.—In describing the character and appearance of the disease, Morse[12a] says, "Plants affected by blackleg are readily distinguished in the field by any close observer, even at a distance (Fig. 150). The affected plants appear more or less unthrifty and usually undersized, varying with the severity of the attack. The branches and leaves, instead of spreading out normally, tend to grow upward, forming a somewhat more compact top, frequently with the young leaves curled and folded up along the mid-rib. Later they become lighter green or even yellow, and the whole plant gradually dies. If the disease progresses rapidly, the stem may fall over quite suddenly and wilt, with very little previous signs of disease other than the upward trend of the foliage noted above.

"The diagnosis of suspected cases is easily confirmed by pulling up the affected plants. Blackleg, as its name indicates, is characterized by a pronounced blackening of the stem below the ground,

Fig. 150.—Potato plant affected with blackleg. Maine Sta.

usually running up one, two, or even three inches above the surface. Sometimes, under very favorable conditions, *i.e.,* continued wet, cloudy weather, especially where plants are growing on a naturally moist soil, the inky-black discoloration may follow up a portion of the stem for several inches above the ground (Fig. 151). During the active progress of the disease, the invaded tissues show a soft wet decay......Usually, the seed tubers attached to affected stems are entirely decayed by a soft rot or have disappeared entirely. ....If young tubers have been formed before the complete invasion of the stem, they are occasionally affected in the same manner...."

The blackened area frequently extends up the stem a foot or more, or even to the extreme tip of the central stem.

Extent of Loss to Crop.—The extent of crop loss from blackleg is relatively small as measured by late blight, rhizoctonia or the fusaria diseases.

Remedial Measures.—Treatment of seed in formalin or corrosive sublimate will destroy surface infection by spores.

Preventive Measures.—Discard all tubers showing stem-end discoloration. Remove all diseased plants and accompanying tubers, if any, as soon as they are noticed in the field. Strictly speaking, there is little excuse for any progressive potato grower having blackleg plants in his potato field, as strict observation of the preventive measures suggested will result in its elimination, since, so far as known, the disease is only transmitted through infected seed.

FIG. 151.—Potato stem completely destroyed by blackleg. Maine Sta.

SOFT ROTS

The soft rots of potatoes are caused by putrefactive bacterial organisms, of which *Bacillus carotovorus* is a good example. Generally speaking, these bacteria are incapable of infecting sound, healthy tubers. They may be regarded in the general category of wound parasites, or as parasites of plant tissues that have been injured through excessive moisture and heat combined which, literally speaking, asphyxiates the living protoplasmic contents of the potato tuber, thus causing a rapid breaking down of the cell structure, which is further hastened by the putrefactive bacteria. All of these organisms convert the flesh of the tuber into a slimy and extremely ill-smelling mass of matter. Frequently, these putrefactive organisms follow late blight infection of the tubers.

Preventive Measures.—The only preventive measures that can be suggested are those pertaining to soil sanitation, such as good drainage and aëration.

BACTERIAL WILT

The disease, *Bacillus solanacearum,* commonly known as bacterial wilt, is one that affects practically all of the food-producing members of the nightshade family, such as the potato, tomato, eggplant, etc. Its occurrence is mostly confined to the southern United States.

Symptoms of the Disease.—The first evidence of infection is a sudden wilting of the whole plant, or of one or more of its stems and finally the whole plant. For a time the wilted stems revive during the night, but gradually they lose their characteristic bright green color and become shrivelled and blackened. An earlier examination of the vascular tissue of the stems would have shown a brownish discoloration somewhat similar to that caused by fusarium wilt. The exudation of tiny drops, of a dirty or yellowish-white-colored liquid, from the cut surfaces of the stem, identifies it as of bacterial origin. In the case of the potato, the discoloration extends into the roots, tuber-bearing stolons infecting the tubers and causing them to decay. Potato plants growing on virgin soil are more apt to become infected with this disease than those on old soil. As a rule it does not, in the aggregate, cause very much loss to the potato crop.

Preventive Measures.—Rotation of crops, soil sanitation, good drainage and aëration will materially reduce infection from the bacterial wilt organism.

STREAK

Occurrence.—The disease known as "streak" is tentatively classified as of bacterial origin, though as yet the causal organism has not been determined. It is not of widespread occurrence in commercial potato fields; in fact, it might be said to be rather uncommon outside of the large seedling collection of the United States Department of Agriculture, where it has occurred, with more or less regularity and in some instances severity, in certain hybrid

FIG. 152.—Potato leaf affected with streak. Note blackened veins and veinlets. (Maine Sta.)

seedlings. It has also been noted by Orton[14a] in a field of Factors' at Puyallup, Washington, in September, 1914.

Description.—Orton describes streak as follows: "Streak is first to be detected on the upper, full grown leaves of the potato plant in the form of elongated or angular spots following the veinlets and invading the parenchyma (Fig. 152). While somewhat more conspicuous on the upper side, these spots are also to be seen on the under side as narrow, discolored streaks along the veins. The typical form may very quickly be recognized, and distinguished from the spots caused by early blight (*Macrosporium solani*); though the more diffuse spots of the streak resemble slightly the macrosporium spots, particularly when the latter also occur on the same plants, as is often the case.

"The destructive progress of the streak is rapid. Shortly after its appearance on the leaflets, as described, the petiole will be found affected and slightly discolored by longitudinal streaks. The petiole collapses, and the leaf then withers and hangs limp; or the petiole breaks at the point of attachment to the stem, and hangs by a thread in a dead and dried condition. Since it is the full grown leaves that are first attacked, there is, at this stage, a circle of dead leaves about a third of the way down from the terminal shoot, while the latter is still green. The hanging dead leaves are quite characteristic of the disease, while all the characters mentioned form a picture that is quickly seen and well remembered.

"A prominent characteristic of streak is the brittleness of the affected parts. The leaves break off very easily and the stem is also brittle......

"The stem begins to turn brown, and dies at a point below the tip. The upper leaves then wilt and die, and the disease progresses downward. Long faint brown streaks appear on the stems also. Apparently, the discoloration is just below the epidermis but not in the vascular bundles. These brown strips are not continuous from leaflet to petiole, nor from petiole to stem. There is no discoloration of the vascular bundles in the lower part of the stem or root, nor are there any other evidences of disease at the root. The several stalks in a hill die separately; all stages may be observed in one hill, from the first spotting of the leaves to the quite dead stalks......No effect on the tubers has been found. The yield is reduced in proportion to the time of onset of the disease."

Preventive Measures.—The only measure possible to take for the control of streak is that of rigidly removing all affected plants as soon as the disease is noticeable. The use of seed from fields known to be free from this disease is also desirable.

MOSAIC

Occurrence.—The disease of the potato known as *Mosaic* is a comparatively new one to American potato growers, having been first observed by Orton[14] (p. 40) in northern Maine, in 1912, but was not found in Wisconsin, Minnesota, Colorado, and other western states during either 1912 or 1913. According to Schultz, Folsom, Hildebrandt and Hawkins,[17] its reported occurrence in 21 states up to 1918 showed conclusively that its distribution was rather general throughout the United States.

FIG. 153.—Plant affected with Mosaic. (Maine Sta.)

Symptoms of the Disease.—The symptoms of the disease are far more pronounced on some potato varieties than on others. The mottled appearance of the foliage, which characterizes this disease from that of others and from which it really derives its name, is marked in some varieties and not very noticeably expressed in others. For example, the disease is rather difficult to detect in the foliage of the Rural varieties, while in the Green Mountain and the Triumph varieties the mottled appearance of the leaves is strikingly apparent (Fig. 153). The mottling is due to a reduction of chlorophyl in localized areas over the surface of the leaf, giving it a mosaic or mottled appearance. Severely infected leaves become crinkled or rugose, with more or less dead tissue along the margin of the leaves. In the advanced stages of mosaic, the plants become much dwarfed in both stem and foliage. While the tubers from the mosaic-infected plants transmit the disease to their progeny, the eye has been unable as yet to detect any symptom of the mosaic disease in the tuber.

Character of the Disease.—Recognized as a transmissible parasitic disease, but as yet, the pathologists have not succeeded in isolating the causal organism. It is strongly suspected by some that the mosaic disease is due to an ultra-microscopic organism. It is transmitted from diseased to healthy plants in the same manner and by the same plant lice as in Mosaic disease. It is also transmitted through infected tubers.

Effect upon Yields.—The evidence at hand indicates that the mosaic disease does cause a material decrease in yields from that of healthy plants. Orton (*l.c.* p. 42) noted a difference in yield between 80 mosaic Green Mountain plants and 80 healthy plants of 22 per cent in favor of the latter; while Wortley[19] claims a difference of over 100 per cent between 200 healthy and 200 mosaic-infected Triumph plants. Murphy[13] secured data on 682 diseased Green Mountain plants and a similar number of healthy plants adjacent to the diseased ones, and found that the yield from the diseased plants was only 58 per cent of the healthy plants. The data presented are sufficient to indicate a marked decrease in yield from mosaic-affected plants, thereby stamping the disease as one to which serious consideration should be given by those interested in the welfare of the potato industry.

Preventive Measures.—Owing to the nature of the disease, only preventive measures can be employed in controlling or holding it in check. The first of these is the elimination of all infected plants in the seed plot as soon as they appear; the second is that of keeping the plants as free from insects, particularly plant lice, as is possible; the third is that of isolating or procuring a mosaic-free strain of seed. As a matter of fact, however, the real problem is that of securing a mosaic-immune variety or strain of some of our present commercial varieties.

LEAF-ROLL

The leaf-roll disease of the potato has, until quite recently, been regarded as a non-parasitic type of disease. At the present time. it occupies about the same position in the minds of the pathologists as does the mosaic disease; it is probably transmitted from diseased to healthy plants in the same manner, though not necessarily by the plant lice or aphids.

Symptoms of the Disease.—As its name indicates, the leaf-roll disease is expressed in a rolling of the leaves, a dwarfing of the plant, a yellowing of the foliage, and an upward rolling of the leaflets about their midrib. In advanced stages the leaves show a distinct tendency to point upward, and quite frequently the upper and younger leaves show a more or less distinct pinkish or purplish tinge on their lower margin. The lower leaves are usually more or less thickened and leathery, and, when handled, make a crackling noise.

Distribution.—Leaf-roll is more or less general in the north-eastern portion of the United States and Canada, and may be found

(A) (B)
Fig. 154.—Effect of leaf-roll disease upon tuber production. (A)—Healthy plant. (B)—Diseased plant. (Photo by E. J. Wortley.)

here and there in western potato fields. In some sections of the East, it is becoming so abundant as to cause concern on the part of those interested in the production or purchase of high grade seed.

Effect upon Yield.—The tubers from leaf-roll plants, at least in the more or less advanced stages, are greatly reduced in size, and are usually borne very close to the main stem of the plant rather than on medium-long tuber-bearing stolons (Fig. 154).

Preventive Measures.—The same preventive measures should be employed for the control of leaf-roll as in the case of the mosaic disease.

POWDERY SCAB

Occurrence.—The existence of this disease, *Spongospora subterranea,* was unknown in the United States prior to papers published by Morse[12] and Melhus[9a] in 1913. It was first reported in North America by Gussow[3a] in February, 1913. It is impossible to more than conjecture the length of time powdery scab had been present, in the potato fields of Maine and the Maritime Provinces of Canada, prior to 1913. A survey of northern Maine, in 1914 and 1915, disclosed the fact that it was widely distributed in Aroostook County, and, judging from the virulence of tuber

Fig. 155.—Stem and roots of potato plants affected with powdery scab. (Maine Sta.)

infection in localized areas and on certain types of soil, one is forced to the conclusion that powdery scab was not a new disease in that region, except in point of observance. Melhus[9b] says: "It seems probable that it was introduced with the heavy shipments of foreign potatoes in 1911." The correctness of this supposition is hardly borne out by subsequent observations regarding its rather widespread distribution. Probably no other disease, outside that of the potato wart, has caused more widespread alarm as to the dire injury it would occasion to the crop, if vigorous measures were not taken to stamp it out. Happily, a closer acquaintance with this disease has resulted in our finding that the powdery scab only thrives under exceptionally favorable environmental conditions. It does not thrive in warm climates and, even when scab-infected and untreated seed stock is planted in the South, the chances are strongly in favor of its not showing any evidence of powdery scab infection.

Distribution.—According to Melhus, Rosenbaum and Schultz,[9c] powdery scab has been found in the following states: Maine, New York, Florida, Minnesota, Oregon and Washington. It is also known to occur in the Maritime Provinces in Canada and in British Columbia. Its general occurrence in northern and central Europe and the British Isles is well known.

Description of the Disease.—The powdery scab disease, like that of the common scab, lives over in the soil. It attacks the

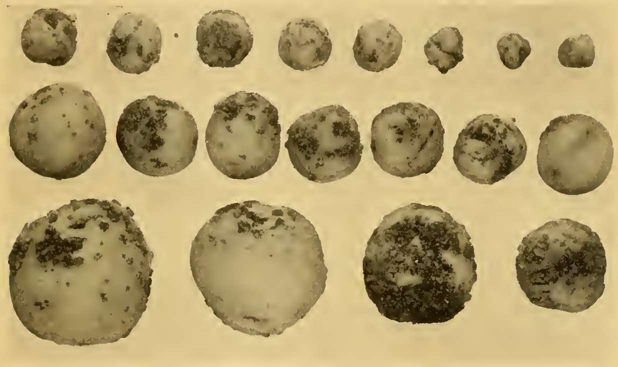

FIG. 156.—Potato tubers showing an abundant infection of powdery scab. (Maine Sta.)

subterranean parts of the potato plant, *i.e.,* the stem, roots, tuber-bearing stolons and tubers (Figs. 155 and 156). The chief injury, of course, comes from the tuber infection, because it reduces the yield and renders the tubers more or less unmarketable for either table or seed stock.

Infected tubers have the appearance of being more or less covered with wart-like protrusions from the surface of the tuber. When freshly dug, the small, grayish-white appearing pustules of the disease are strikingly apparent (Fig. 156); but later on, as the surfaces of the tubers dry off and the epidermal covering of the common scab, except that the cup-like depressions of the powdery pustules becomes ruptured, it more nearly resembles those of the scab pustules are filled with brownish spores or spore masses.

Powdery scab also differs from the common scab in that the disease may continue to be active in storage; whereas, the common scab is never active after the tubers are removed from the ground. It is chiefly disseminated through the planting of infected tubers. Other distribution agencies are spore-containing receptacles, such as second-hand sacks, barrels or baskets in which the crop is gathered; and lastly, by means of transporting infected soil by the feet of farm animals, man, farm implements, etc.

Preventive or Remedial Measures.—While it has not been definitely proven that the ordinary seed treatment recommended for common scab and rhizoctonia is an absolutely effective remedy for powdery scab, there is evidence that tends to indicate that such treatment does more or less completely inhibit the disease. The principal methods of control are preventive rather than remedial. They consist in the selection and planting of clean seed, and in the practice of a definite crop rotation system.

SPINDLING SPROUT

Description.—As yet, there is no direct evidence that the spindling sprout of the potato is caused by either a fungous or bacterial parasite. Tubers affected by spindling sprout produce numerous weak, needle-like sprouts, usually from most of the eyes, instead of a single, strong, vigorous shoot as in the case of normal seed stock. Pathologists and physiologists are not agreed as to the cause of this phenomena. Various theories have been advanced, some of the more plausible being as follows: Spindling sprout may be the result of the tubers having developed during a hot, dry period and, being subjected to a high soil temperature, their vegetative vigor is seriously impaired. Exposure to high storage temperatures is also thought to be another cause. It would appear from these several theories that spindle sprout is simply an expression of impaired vegetative vigor, rather than the result of some causal organism.

Preventive Measures.—The only preventive measures necessary are the removal of all weak plants from the seed plot and the planting of strong healthy seed stock.

NET NECROSIS

Description.—Our knowledge of "net necrosis" is about on a par with that of spindling sprout. In fact, it is rather doubtful if the cause of this trouble is as well known as that of spindling sprout. It is thought that net necrosis may be caused by unfavorable growing conditions when the tubers are developing. Similar symptoms have been observed in tubers exposed to temperatures below the freezing point, in other words, that had been frosted. Tubers affected with net necrosis can only be detected by the removal of a thin slice from the stem-end of the tuber. The presence of radiating brownish or blackish lines is fairly good evidence that they are affected with this trouble.

Preventive Measures.—All seed tubers showing discoloration of the flesh at the seed end should be discarded. Plant only healthy stock.

CURLY-DWARF

Description.—This type of potato disease is in many respects quite similar in its appearance to that of the true leaf-roll. Orton[14] (p. 38) describes its appearance as follows: "The stem and its branches, the leaf petioles, and even the mid-ribs and veins of the leaves all tend to be shortened, in many cases to a very marked extent, and particularly in the upper nodes of the plant, so that the foliage is thickly clustered. The diminished growth of the leaf veins, in proportion to the parenchyma, results in a bullate, wrinkled leaf, often strongly curled downward. There seems also to be a tendency to form more secondary branches than is normal, and, as these remain short and have curly leaves, the compactness of the plants is more striking. The stems are also very brittle. The color of the foliage in curly-dwarf is typically a normal green, except that in very severe or advanced cases there is a lighter green or yellow color, sometimes accompanied by brown or reddish flecks in the leaves where the tissues are dying. Typical curly-dwarf is readily distinguished from leaf-roll by the wrinkled or downward curling of the leaves, the normal color of the foliage, and the firmness of the leaves which do not lack turgidity."

As might be expected, the tuber yield from curly-dwarf plants is very much reduced from that of normal ones.

The nature of the disease, like that of streak, has not been determined. It is thought by some pathologists to be simply an advanced stage of mosaic, but, as yet, there is not sufficient evidence at hand to fully confirm this supposition.

Occurrence and Distribution.—Owing to the confusion now existing in the minds of many regarding the identity of mosaic-dwarf and curly-dwarf when they depart ever so slightly from the purely distinctive characters of one or the other, it is difficult to express an opinion as to the general prevalence of one or the other type of disease in a given locality. Orton is of the opinion (*l.c.* p. 39) "that curly-dwarf plays a large rôle in the deterioration of potatoes." The personal observations of the writer would incline him to believe that curly-dwarf is much more prevalent in the northeastern portion of the United States. In fact, typical curly-dwarf plants are rarely noted in the western states. It has been more or less common among certain seedling potato strains in the Department's collection.

Preventive Measures.—The same preventive measures should be pursued in the control of curly-dwarf as in that of leaf-roll and other related types of disease.

TIP-BURN

Description.—Tip-burn is a purely physiological trouble, due to the failure of the roothairs of the plant to furnish a sufficient supply of moisture to the leaves during dry, hot, windy and sunshiny days, when the rate of moisture transpiration from the leaves is greater than the rate of supply. This causes a wilting and burning of the younger and more active cell tissues which are, of course, the extremities of the younger leaves. When this burning or, more strictly, scalding of the leaf tissue is sufficiently severe, the cell tissues are destroyed—the tip of the leaf drying up. If the heat and drought is sufficiently prolonged, the whole leaf may be destroyed.

Control.—The surest method of preventing or minimizing tipburn is by providing optimum conditions for the healthy and normal development of the potato plant. Land well supplied with organic matter, deeply plowed, thoroughly fitted and intelligently cultivated, so as to induce deep rooting of the plants and conserve moisture, coupled with thorough spraying of the plants with Bordeaux mixture, furnishes the best insurance against injury from tip-burn.

ARSENICAL INJURY

Improperly used arsenical poisons frequently cause serious injury to the foliage of the potato. Arsenical injury is frequently confused with early blight. Both produce brownish or blackened more or less irregular areas on the potato leaf, and also have more or less darkened concentric rings in them (Fig. 157).

FIG. 157.—Arsenical injury of potato foliage; sometimes mistaken for early blight. (Maine Sta.)

Preventive Measures.—Do not dust the plants with straight Paris green. If it seems desirable to use dry powdered Paris green, mix it with at least 20 parts of land plaster, air-slaked lime or any other form of finely divided dry lime. If liquid applications of Paris green are made, use at least two pounds of lime to 50 gallons of the liquid. The lime neutralizes the free arsenious acid and thus prevents injury from burning. Other forms of arsenical poisons, which have white arsenic or arsenite of soda as their base, should be carefully tested for the presence of free arsenious acid; neutralize with lime if necessary.

QUESTIONS ON THE TEXT

1. Name some of the principal fungous parasites of the potato.
2. What is the estimated loss in some seasons, from late blight alone in the United States?
3. Into what two groups or types of diseases are potato troubles classed?
4. What is meant by a parasitic disease?
5. What is meant by a non-parasitic disease?
6. What parts of the plant are attacked by early blight?
7. How much injury does the potato plant sustain from early blight? Give various estimates cited.
8. What are the characteristic symptoms of early blight on the foliage?
9. What are the normal methods of infection?
10. How does the disease pass the Winter, and whence the source of new infections?
11. How early does the disease make its first appearance on the early and the late crop?
12. What preventive measures may be employed?
13. How does the late blight differ from early blight?
14. Why is late blight more destructive than early blight?
15. In what portions of North America and Europe is late blight prevalent?
16. What is the extent of its distribution?
17. Give a brief account of the life history of late blight.
18. What are the conidiospores? How are they borne?
19. How do the conidiospores infect the leaves of the potato?
20. How does tuber infection take place?
21. What control measure may be employed to lessen the prevalence of this disease?
22. What control measure can be employed to prevent infection?
23. Of what importance is a good sprayer and intelligent application of spray materials?
24. What kind of climatic conditions are favorable to late blight infection?
25. When should the first application of Bordeaux be made?
26. Describe the typical symptoms of fusarium wilt.
27. What species of fusarium is responsible for the fusarium wilt?
28. What are the two sources of infection?
29. What are some of the control measures that may be employed?
30. How may a large per cent. of fusarium-infected tubers be rejected when cutting them for planting?
31. How does the fusarium dry rot differ from fusarium wilt? What are the different forms of dry rot?
32. What is the nature of the injury caused by *F. trichotheciodes?* How widely prevalent is it?
33. How does verticillium wilt differ from fusarium wilt? Describe it.
34. What preventive measures can be used?
35. Of what economic importance is the disease known as rhizoctonia or black scurf? Give the nature of the loss.

36. What are the chief distinguishing characters of plants infected with rhizoctonia?
37. What preventive measures are suggested?
38. What is the cause of common scab? What is the nature of its injury?
39. What remedial measures are recommended for its control? What preventive measures?
40. What is the effect of turning under green manuring crops to correct soil alkalinity?
41. What are the distinguishing characteristics of silver scurf?
42. What is the best preventive measure?
43. When was the potato wart disease first recognized in North America? In United States?
44. Describe and give the life history of the wart disease.
45. What American varieties are immune to the disease?
46. What causes the leak disease of the potato? Describe it.
47. What are the most effective preventive measures?
48. What causes the blackleg disease of the potato? Describe it.
49. What remedial and preventive measures are recommended?
50. What causes the soft rots of the potato?
51. Are the bacteria which cause soft rot parasitic or non-parasitic? Why do you say so?
52. What control measures are suggested?
53. What organism causes the bacterial wilt of the potato? Describe the symptoms.
54. What preventive measures are suggested?
55. What is the cause of "streak"? How widespread?
56. Describe the general appearance of a streak infected plant.
57. What preventive measures are suggested?
58. When was the mosaic disease first observed in America? How general is it?
59. Give symptoms and nature of the disease.
60. How is it transmitted?
61. To what extent does it affect yields?
62. What preventive measures are recommended?
63. What is the leaf-roll disease? Describe the symptoms.
64. What effect has it upon the yield?
65. What preventive measures are suggested?
66. When and where was powdery scab first observed in North America? In United States? Describe it.
67. What prevents its obtaining a foothold in the South? Give its climatic preferences.
68. What are the common distributive agencies of the disease?
69. What preventive or remedial measures are suggested?
70. What causes spindling sprout?
71. What effect has prolonged storage upon the germination of tubers and the size of sprouts?
72. What preventive or control measures are suggested?
73. What is known about net necrosis? Describe the diseased tubers.
74. What preventive measures are advocated?
75. How does "curly-dwarf" differ from leaf-roll? Give symptoms and effect on yield.
76. Give distribution and preventive measures.
77. What causes tip-burn? Describe the injury, and give preventive measures.
78. Describe arsenical injury and tell how to avoid it.

QUESTIONS SUGGESTED BY THE TEXT

1. Name the potato diseases in order of their most frequent occurrence locally.
2. What proportion of the local growers take measures to prevent common scab? What measures?
3. What proportion of the local growers spray for late blight?
4. What pressure is used? How many nozzles to the row?
5. To what extent is dry rot injurious locally?
6. What local losses have been found due to soft rots?
7. What diseases seem to be increasing in local importance?
8. Collect specimens of as many potato diseases as possible.

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CHAPTER XVI

INSECT AND ANIMAL PARASITES OF THE POTATO AND METHODS OF CONTROLLING THEM

The potato has numerous insect pests and at least one that is not a member of the insect family. These combined enemies of the potato plant and tuber take an annual toll of many millions of dollars from the potato crop alone. A goodly portion of this loss is due to the failure of the grower to sufficiently protect his crop from the ravages of these pests. Unfortunately, however, a considerable portion of the injury is caused by insect or animal pests rather difficult of control, such as the flea beetle, aphid, leaf-hopper, tuber-moth and eelworm. These enemies of the potato naturally divide themselves into different groups, according to whether they have chewing or sucking organs, the parts of the plant they attack, and, in the case of the eelworm, their method of reproduction.

Group classification of insect and animal parasites.

A. Potato Insect Parasites

I. Leaf-chewing and mining insects.

1. Colo. potato beetle 2. Flea beetle 3. Three-lined beetle 4. Tortoise beetle 5. Blister beetle 6. Tuber moth—see section II.	Spray plants with arsenical poisons, such as Paris green, arsenate of lead, arsenite of zinc, etc.

II. Stem- and tuber-eating insects.

7. Stalk borer 8. Stalk weevil	Crop rotation, and destruction of all infested plants.
9. Cutworm 10. White grub 11. Wireworm	Poisoned bait; crop rotation; fall plowing of land.
6. Tuber moth	Covering tubers with heavy layer of soil. Prompt harvesting of crop when ripe. Fumigation of storage house. Use of insect-free seed.

III. Sucking insects.

12. Potato aphid	Spray with contact insecticides.
13. Four-lined leaf-bug	
14. Leafhopper	Spray with contact insecticides and with Bordeaux mixture as a repellent.

Preventive and Remedial Measures.

B. Potato Animal Parasites

IV. Piercing and sucking.

15. Eelworm	Crop rotation. Use of uninfested seed.

COLORADO POTATO BEETLE

Occurrence and Distribution.—According to Britton,[4] the Colorado potato beetle, *Leptinotarsa decemlineata,* Say, was unknown to the potato growers of North America prior to 1855. About that period the frontier of potato growing reached the region where these beetles were native, and they developed such a liking for the foliage of the potato plant that they soon forsook the native solanums, on which they had been feeding, and became a serious pest of this crop. It is supposed that they crossed the Mississippi river about 1864 and reached the Atlantic seaboard states some ten years later. As there was then no practical equipment for spraying plants, the potato grower was obliged to hand-pick the bugs in order to prevent serious injury to the plants (Fig. 158). This laborious operation was soon displaced by the use of arsenical poisons, of which Paris green was the most commonly employed. At first, much of the spraying was done by hand, by the use of a whisk-broom or wisp of straw. This crude method was soon followed by the hand pump with spray nozzle attachment. The evolution of the spray pump has been rapid until, at the present time, there are many highly efficient mechanically, as well as gasoline, operated spray machines which do effective work (Fig. 159).

Description.—The adult potato beetle is about three-eighths of an inch long and yellow in color, with five black stripes running lengthwise on each wing-cover and a series of black spots on the thorax. One female may lay from 500 to 1,000 eggs. The eggs are of a bright yellow color, about one-thirty-second of an inch in length. They are deposited in clusters on the under side of the leaves (Fig. 160) and hatch out in about a week. The larvæ grow rapidly and, when nearing full size, consume a large amount

FIG. 158.—The old and laborious method of controlling the Colorado potato beetle.

FIG. 159.—The modern and less laborious method of controlling the Colorado potato beetle. Courtesy Bateman Manufacturing Co.

of foliage. The full grown larva is a stout, fleshy grub, with a black head and black spots over body (Fig. 161). They reach maturity in about three weeks, after which they enter the ground to pupate. Two to three generations are produced in a season.

The last generation passes the Winter in the ground, emerging as a mature beetle early the next season.

Remedial Measures.—While the potato beetle is a serious enemy of the potato plant if left unmolested, it is, in reality, one of the most easily controlled. As it is a leaf-eating insect, the manifest thing to do is to keep the foliage of the plants well covered with some form of arsenical poison. Paris green, lead arsenate

FIG. 160.—Eggs of the Colorado beetle, twice the natural size. (Conn. Sta.)

and zinc arsenite give very satisfactory results when used intelligently. Arsenical poisons may either be applied as dust or liquid sprays. While dust sprays may give very satisfactory results, the writer prefers to use liquid sprays. The plants should be dusted or sprayed at about the time the first batch of eggs are hatching out, as they are much more easily poisoned when they are a few days old.

THE POTATO FLEA BEETLE

Description and Life Habits.—The potato flea beetle, *Epitrix cucumeris,* Harris, is a small, black, jumping beetle, slightly over one-sixteenth of an inch in length and about one twenty-fourth of an inch in width; the antennæ and legs are yellowish, but the body parts, including the head, wing covers and thorax, are jet black.

The mature beetle eats small holes through the potato leaf, giving it the appearance of being artificially perforated (Fig. 162). When present in large numbers they cause very serious injury to the foliage and, as a result, very materially lessen the yield. The beetle lays its eggs under rubbish on the ground. The larvæ have

Fig. 161.—Larvæ of the Colorado potato beetle at work. (Conn. Sta.)

slender thread-like bodies. They feed on the underground parts of the plant, particularly upon the tubers. I have personally observed dozens of larvæ partially burrowed into the tuber. In some sections, the tubers are so seriously injured by the flea beetle larvæ as to be unsalable. The number of broods varies from one to two according to locality. It has been found that by delaying the date of planting, in some sections, it is possible to avoid a large portion of the injury caused by the first brood.

Remedial Measures.—Although arsenical poisons are quite generally recommended by the entomologist for the control of the flea beetle, the writer is yet to be convinced that poisons are an effective control measure. The flea beetles are difficult to control, as they usually work from the lower side of the leaf and do not always puncture clear through the leaf; therefore, poisons on the upper surface of the leaf are not likely to find their way into the

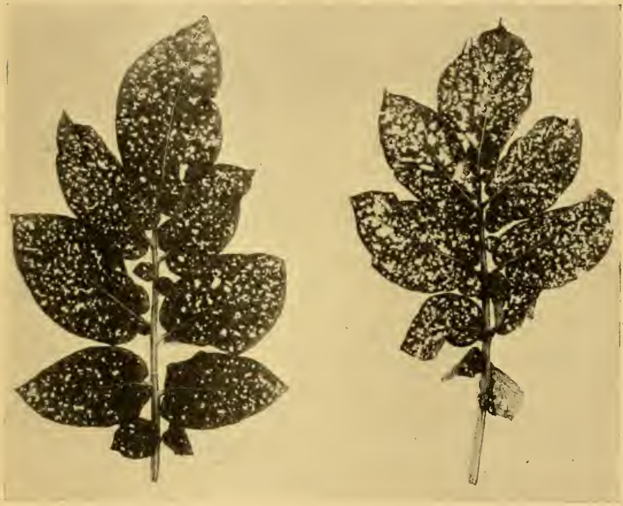

Fig. 162.—Potato leaves severely injured by flea beetles. (Maine Sta.)

digestive tracts of the flea beetle. The most hopeful measure of control is that of thoroughly covering the foliage with Bordeaux mixture. The Bordeaux covered foliage seems to be distasteful to the beetle, and in that way serves as a repellent rather than a remedy. A mechanical device for trapping the flea beetles was tested at the Ohio State University, some years ago, by Metcalf,[15] with apparent success. This device consisted of a soap box with cover, the front end removed, nearly half of the central part of the bottom and a good-sized notch in the lower side of the rear end cut away. The inside of the box was coated with tangle-foot, and when pushed forward along the row the flea beetles, jumping, when disturbed, were caught in the sticky material. By mounting this box on wheels and making some minor changes, it caught flea beetles at the rate of over 25,000 per acre. The use of this or some similar device suggests the possibility of exercising a fairly complete control of this insect pest.

THREE-LINED POTATO BEETLE

Description.—The three-lined potato beetle, *Lema trilineata*, Oliv., is yellow with three black stripes running lengthwise of its body (Fig. 163). It bears some resemblance to the striped cucumber beetle but is somewhat larger, with a constricted thorax

Fig. 163.—Three-lined potato beetle. Adults on leaf, natural size.

Fig. 164.—Larvæ feeding upon leaf, natural size. (Conn. Sta.)

marked with two black dots. The eggs resemble in color those of the Colorado beetle, but are smaller and more apt to be deposited on the mid-rib of the leaf, instead of in clusters on the laminal portion. The larvæ differ also from the Colorado beetle in their habit of feeding, as they usually line up in a row on the under surface of the leaf and devour it as they move from tip to base of it, leaving the larger veins intact (Fig. 164). The larvæ are buff or tan colored.

There are two generations each year. The winter is passed in the pupa stage.

Remedial Measures.—The same measures are used to control this pest as are employed against the Colorado beetle.

TORTOISE BEETLES

Description.—Tortoise beetles are only occasionally enemies of the potato plant. They are small hemispherical beetles, with a rather conspicuous marginal flange somewhat resembling the tortoise in shape (Fig. 165). They usually feed upon the wild morning glory and sweet potato, but are sometimes found upon the

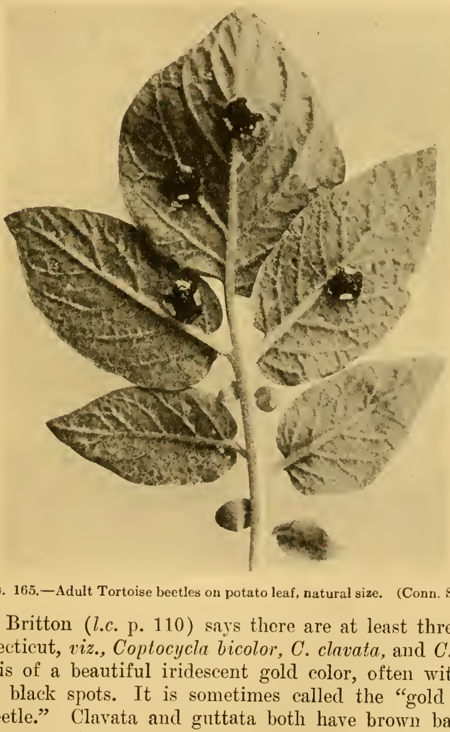

Fig. 165.—Adult Tortoise beetles on potato leaf, natural size. (Conn. Sta.)

potato. Britton (*l.c.* p. 110) says there are at least three species in Connecticut, *viz., Coptocycla bicolor, C. clavata,* and *C. guttata.* Bicolor is of a beautiful iridescent gold color, often with inconspicuous black spots. It is sometimes called the "gold bug" or "gold beetle." Clavata and guttata both have brown backs with translucent marginal flange. The dark portion in guttata is more or less interspersed with translucent spots. Clavata is larger than guttata, and the brown area is quite rough.

The eggs are laid singly on the veins or stems of the leaves; each egg is covered with a small mass of black excrement. The larvæ are dull green, oval, with lateral projections or spines, and feed on the under surfaces of the leaf. Their excrement is carried on the caudal spines. Only one generation is produced each season. The adult beetles pass the winter in crevices, and appear on the potato plants during the month of May in Connecticut. The injury to the potato plants caused by these beetles is usually not a serious one.

Remedial Measures.—They are readily controlled by arsenic poisons.

BLISTER BEETLES

Description.—Blister beetles only occasionally feed upon the potato plant. They are about half an inch long and about three-sixteenths of an inch in width, and have soft wing covers (Fig. 166). The principal species are the black blister beetle, *Epicauta pennsylvanica,* DeG.; the margined blister beetle, *E. marginata,* Fabr.; the striped blister beetle, *E. vittata,* Fabr.; and the ash gray blister beetle, *Macrobasis unicolor,* Kby.; all of which occur in great numbers in certain seasons. The blister beetles fed upon potatoes long before the Colorado beetle and are sometimes called "old-fashioned potato beetles." They feed upon a variety of plants besides the potato, among which might be mentioned the golden rod and cultivated aster. The larvæ do not feed upon potato foliage as do the adult beetles.

Remedial Measures.—Being leaf-eating insects, they may be controlled by arsenical sprays.

POTATO STALK- AND STEM-BORERS

The stalk- and stem-borers, like the blister beetles, do not confine their ravages to the potato plant alone; tomatoes, corn, rhubarb, sugar beets, dahlias, lilies and other plants furnish food for the larvæ of these two insects.

Life History and Habits.—The adult of the potato stalk-borer *Papaipema nitela,* Gn., is a purplish gray moth having a wing spread of about one and a quarter inches (Fig. 167). The eggs are deposited in the stem of the potato and the newly hatched larva begins tunnelling through the pith of the stem. The full grown larva is one and a half inches long. It passes through the pupal stage in the tunnel made by the larva, and remains in the stem until it emerges as a moth the following spring.

The life history of the potato stem-borer, *Gortyna micacea,* Est., is somewhat different from that of the stalk-borer. According to

Fig. 166.—Adult margined blister beetles feeding on potato leaves, natural size. (Conn. Sta.)

Brittain[3]: "The eggs are laid by the female moth during the latter part of August and September. They are doubtless deposited on various weeds, though we have found them only on couch grass. They are very small, pinkish colored eggs, faintly ribbed, and are laid loosely sometimes in rather large numbers on the stem partially surrounded by the leaf sheath. The larvæ hatch out in June and make their way to a suitable food plant, where they bore a tiny entrance hole in the stem, usually at the surface of the ground. They bore in the stem or in the crown of the plant until some time in August, and then enter the ground where they transform to pupæ, emerging in late August or September as adult moths."

Occurrence.—The stalk-borer is not a serious pest, as it is seldom found in abundance in any locality. The distribution of the stem-borer is not given by Brittain, but it is evidently fairly common in Nova Scotia.

Preventive Measures.—As it is impossible to reach the larvæ with arsenical poisons, the only control measures that can be employed are the destruction of the old potato stems and all weeds

Fig. 167.—Adult Stalk-borer, natural size. (Conn. Sta.)

known to be infested with the hibernating pupæ, or that carry the eggs of the stem-borer. Rational crop rotation practices are also helpful.

POTATO-STALK WEEVIL

Occurrence.—The potato-stalk weevil, *Trichobaris trinotata*, Say, according to Fayville and Parrot,[10] was collected in Douglas County, Kansas, in 1873 by Professor Snow, and was first recorded by Popenoe.[18] He reported it as being common in eastern Kansas. It was particularly abundant in 1897, causing more or less serious injury to Kansas potato fields.

Habits and Life History.—The potato-stalk weevil like that of the borer is not confined in its food plants to the potato alone.

The horsenettle, cocklebur, jimson weed and ground cherry are common host plants for this insect pest.

The adult is a small snout-beetle, belonging to the same family of insects as the plum curculio. It is of an ashy-gray color, about one-fifth of an inch long and is marked with three black spots at the base of its wing covers. The female deposits her eggs in the stem, main, and secondary branches, by first cutting a slit about one-twelfth of an inch long in which she deposits one egg. The same operation is repeated for each egg deposited. These eggs hatch in from seven to eleven days, and the small larva begins to work its way downward towards the root of the stalk. After channelling down a distance, the larva turns round and works upward, enlarging the channel as it moves along. At maturity, the larva averages from three-eighths to one-half of an inch in length, with a brown head and dark-colored mouth parts. The body bears a few light-colored hairs. The pupal stage lasts from about eight to eleven days. The mature beetle remains in the stem until the following spring.

Preventive Measures.—Employ the same preventive measures as for the stalk-borer.

CUTWORMS

As a rule, cutworms are not a serious pest of the potato. Where very abundant in the soil they may cut off a good many of the young stems, but rarely cause injury after the plant is six to eight inches high. They usually cut the stem off near the surface of the ground.

Life History.—Cutworms are the larvæ of noctuid moths and there are several species, three or four probably being responsible for most of the injury. There is but one generation each year, the moths emerging and the eggs being laid the latter part of the summer. The cutworms become partially grown before winter, after which they burrow deeply in the soil and remain there until spring. Their chief damage is done in the early spring, when the vegetable plants are young and tender.

Remedial Measures.—As the cutworm is not a leaf eating insect and lives almost entirely in the ground, the usual methods employed to control leaf eaters are of no avail. The most effective remedial measure is to partially bury some poisoned bait. A poisoned and sweetened bran mash scattered over the soil or partially buried in it will destroy large numbers of them. The formula recommended by Britton (*l.c.* p. 112) is as follows:

Wheat Bran	5 pounds
Paris green or white arsenic	5 ounces
Lemon or orange	1 fruit
Molasses	1 pint
Water	7 pints

Mix the dry poison and bran together, then squeeze the juice from the lemon or orange into the water, cut the pulp and peel

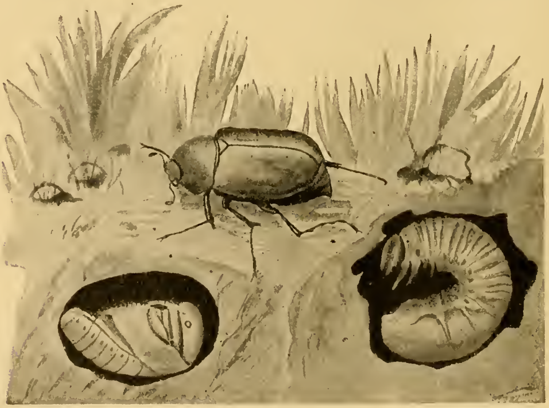

FIG. 168.—"June bug"; larva or white grub pupa and adult. (After Linville and Kelly.)

into fine pieces and add them to the water, after which add the molasses and stir. Mix this syrup thoroughly with the poisoned bran. (Young clover stems may be substituted for the bran). Fall plowing the land is also a desirable practice.

WHITE GRUBS

Habits and Life History.—The natural food of the white grubs, *Lachnosterna,* like that of the cutworms and wireworms, consists largely of grass roots, but they also attack the underground parts of other plants, among which is the potato. The chief damage to the potato by white grubs consists in their consumption of portions of the tubers. When numerous enough, they may completely destroy the whole crop; such an occurrence is very rare, however, and only happens when the crop is planted on old sod land. White grubs are the larvæ of the May or June beetles (Fig. 168). The life cycle of the chief species requires three years for its completion.

The female beetle deposits her eggs in the soil at a depth of from one to eight inches. The young grubs feed on decaying vege-

FIG. 169.—Potato tubers injured by wire worms. (Conn. Sta.)

tation, but soon begin to eat the roots of living plants. They are most destructive to vegetation during the second year of their existence, but may also cause serious damage to early spring crops, the third year.

Preventive or Control Measures.—One of the most effective control measures that can be employed is that of crop rotation. Grubs are seldom present in land that is handled on a short rotation basis, say three or four years, and may generally be expected in large numbers in old sod land, or in land that has been allowed to grow weeds for several years. Poisoned bait, such as recommended for cutworms, may be used on relatively small areas. All land suspected of being infested with white grubs should be plowed in the fall, in order to expose as many as possible of the white grubs to insect-devouring birds.

WIREWORMS

Life History and Habits.—Wireworms are the larvæ of "click" or "snap" beetles, belonging to the family Elateridæ. They include several species which feed upon cultivated plants, most of which belong to three genera, Agriotes, Melanotus and Drasterius. These larvæ are small, hard, cylindrical, and generally of a tan or reddish-brown color. It requires from three to five years for the wireworms to pass through their complete life cycle, all of which time, except their adult stage, is spent in the soil. While it is possible that the wireworms may cause considerable damage to the roots and lower portion of the stem of the potato plant, the injury is usually unnoticed. The chief observable injury is that caused by the wireworm boring into the seed tuber, often entirely destroying it and, in attacking the new tubers, making them unsalable and causing material waste in preparing those that are only slightly tunnelled (Fig. 169).

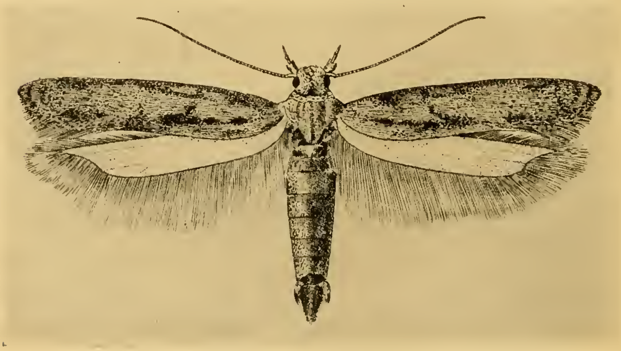

Fig. 170.—Potato tuber moth greatly enlarged. (Bureau of Entomology.)

Preventive or Control Measures.—The same control measures should be employed against the wireworms as those recommended for white grubs and cutworms.

THE POTATO TUBER MOTH

The potato tuber moth, *Phthorimæa operculella,* Zell., was first mentioned in literature by Captain H. Berthon[2] in 1855. Berthon stated that it had proved very damaging to potatoes in Tasmania in 1854.

Occurrence and Distribution.—It was first observed in the United States in 1856, having been found in San Francisco, California. In 1873, Zeller[21] published the first technical description of the tuber moth which he made from specimens collected in Texas. According to Graf[12] its distribution in the United States and foreign countries was as follows, in 1917: California, Texas, Florida, North and South Carolina, and Virginia. The foreign

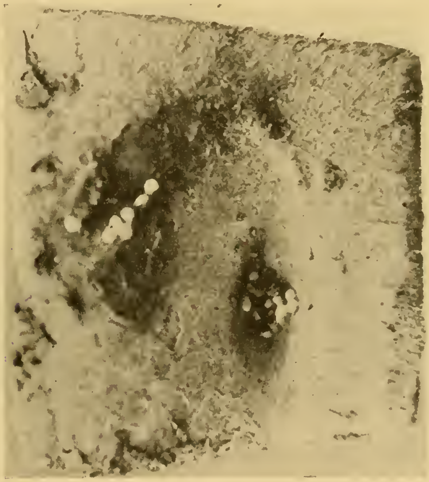

Fig. 171.—Egg clusters of potato tuber moth deposited in and around potato eye. (Bureau of Entomology.)

countries are Tasmania, New Zealand, Australia, Algeria, South Africa, India, Southern Europe, Italy, France, Spain, Canary Islands, Azores, and Hawaii.

Origin.—While there is more or less controversy regarding the origin of the tuber moth, the bulk of the evidence would seem to justify the assumption that it is of American origin, probably from South America.

Description.—The potato tuber moth is a small, gray, night-flying moth having a wing expanse of a little more than half an inch (Fig. 170.) It usually hides under clods or rubbish during the day time. The adult moth is comparatively short-lived. The male lives from 1 to 14 days and the female, 2 to 22 days. The female lays her eggs on the under side of the potato leaf, the petiole of the leaf or the stem of the plant. When potato tubers are accessible, the eggs are also deposited on the tuber (Fig. 171). Generally speaking, however, as long as the plants are green and thrifty, the female oviposits on leaf or stem rather than on tuber. The period of egg incubation varies from 5 to 34 days, depending on

Fig. 172.—Injury caused by the tuber moth to the leaves and tips of shoots of the potato plant. (Bureau of Entomology. U. S. Dep't of Agriculture.)

season of year and temperature. The newly hatched larvæ seldom move about but commence at once to mine into leaf, stem or tuber, as the case may be. Those on the leaves eat through the epidermal structure and proceed to mine between the upper and lower epidermal layers of the leaf (Fig. 172). They may tunnel down the petiole into the stem of the leaf or may confine their mining operations entirely to the leaf blade. Larvæ, hatched from eggs deposited in the eyes or cracks of the tuber, at once begin burrowing into the tuber (Figs. 173 and 174). The larvæ feeding period ranges from 14 to 69 days. The longer period usually occurs in the storage house at low temperatures. The period of pupation varies from 8 to 56 days (Fig. 175). Larvæ feeding on the plant usually pass the pupal stage in curled or rolled up leaves, those in the stems partially protruding from old burrows, while others pupate under clods or rubbish.

Amount of Injury.—The amount of injury caused to the potato crop by the tuber moth is directly dependent upon the prevalence of the insect and the way in which the crop is handled. As a rule, the injury caused to the plant itself is not serious, though

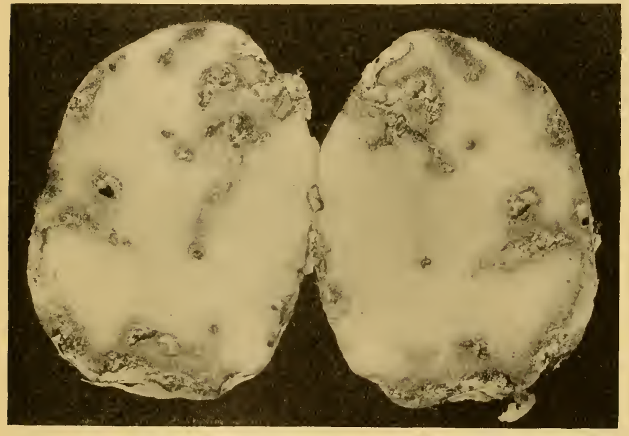

FIG. 173.—Tuber injured by the larvæ of the potato tuber moth Phthorimæa operculella. (Bureau of Entomology, U. S. Dept. of Agriculture.)

under certain conditions, they might very materially reduce the yield. The chief injury ordinarily comes from tuber infestation. The larvæ burrow through the flesh of the tuber, rendering it unsalable. When infested tubers are stored and not fumigated, heavy losses follow. Thus far, the potato tuber moth is only a serious pest of the potato in California. In other localities in the United States, it has usually been associated with other plants, such as the tomato, eggplant and tobacco.

Preventive and Remedial Measures.—The best preventive measures to employ in combating the tuber moth are (1) soil sanitation; (2) crop rotation; (3) protection of tubers by ridging up soil over them; (4) the prompt harvesting of the crop as soon as it is ready to dig; (5) the gathering of the tubers as soon as possible after digging them. Soil sanitation consists in the removal and destruction of all unsalable potatoes as soon as the marketable crop is gathered. Crop rotation is always desirable.

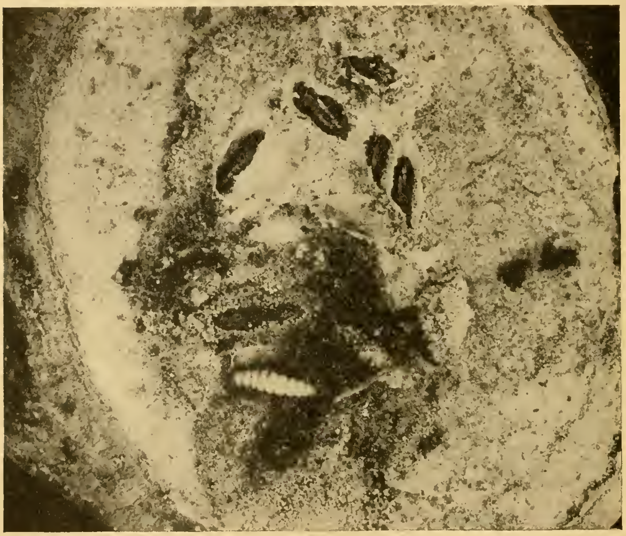

Fig. 174.—Section of a potato tuber showing larva and pupæ of the potato tuber moth. (Bureau of Entomology, U.S. Dept. of Agriculture.)

Tuber infection may be materially lessened by slightly ridging the soil over the tubers. This practice prevents the female moths from reaching the tubers. The prompt harvesting of the crop before the vines are fully dead lessens the chances of tuber infestation, as the moth, ordinarily, prefers to lay eggs on the plant, rather than on the tubers; as soon, however, as the vines are dead, the eggs are laid on the tubers if they are within reach of the female moth. It is desirable to gather the tubers as quickly as possible after they are dug, because the disturbed moths fly about even during daylight, and oviposit on the newly harvested tubers.

If the tubers are known to be infested by larvæ or to carry eggs, they should be fumigated as soon after putting them in the storage house as possible.

POTATO APHIDS

There are at least two distinct kinds of aphids or plant lice that cause more or less injury to the potato crop. These two aphids are known scientifically as *Macrosiphum solanifolii,* Ashm.; and

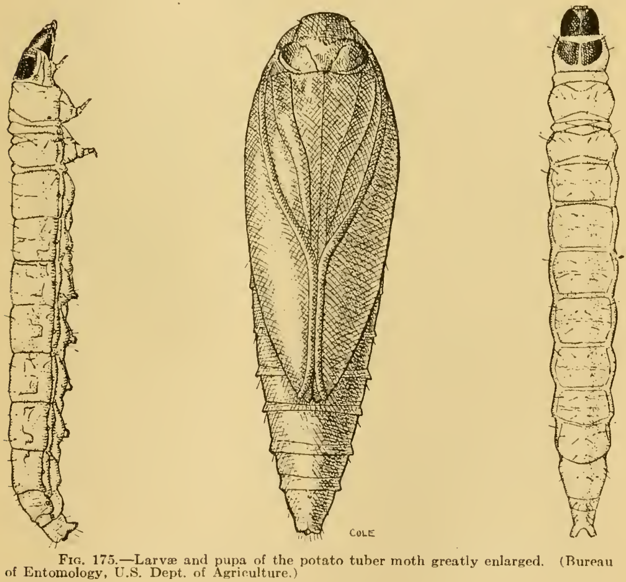

FIG. 175.—Larvæ and pupa of the potato tuber moth greatly enlarged. (Bureau of Entomology, U.S. Dept. of Agriculture.)

Myzus (Rhopalosiphum) persicæ, Sulzer. The first is commonly known as the pink and green plant louse, on account of portions of some broods being pink and others green. The second is known as the green peach or spinach aphid. These plant lice belong to the class known as sucking insects; that is, they live upon the juices of their host plant, which they suck from it by inserting their beaks into its tissues. In 1917 and 1918, potato aphids were quite generally prevalent throughout the whole northeastern potato-growing section of the United States, causing an untold amount of damage to the crop. In some localities they were so abundant that they actually sucked out so much of the juices of the potato plant as to cause a premature ripening with a consequent material lessening of the crop yield. In 1919 and 1920, they were not so abundant and little damage resulted. In 1907, Dr. Edith M. Patch[17] reported a serious outbreak of plant lice on potatoes in Aroostook County, Maine, during the seasons of 1904, 1905 and 1906. Apparently, therefore, these periodic recurrences of the potato aphid are the result of the rise and fall of its parasitic enemies of which it has a number.

The rather recent discovery that the mosaic disease of the potato is transmitted from diseased to healthy plants, through the agency of these two plant lice, serves to still further emphasize the necessity of controlling or combating these insect pests by every known practical method.

Life History of These Two Plant Lice.—The pink and green plant louse over-winters in the egg stage. In the Spring, the egg hatches and produces what is known as the "stem mother." This insect, in from 10 to 12 days' time, begins to produce living young, all of which are gravid females and capable of producing new batches of similar living young in about the same period of time as the "stem mother." The rapidity of this process of multiplication is best understood from some observations made at the Ohio Station, in which a single aphid of this species was caged on an uninfested plant. At the end of 12 days, her progeny (daughters and grand-daughters) totalled 76, five of which were already producing young. It requires little imagination to picture the rapidity of the increase from this point on. Most of the broods produced during the season are wingless (Figs. 176 and 177), but there are occasional winged broods. The winged broods migrate much more rapidly than the wingless ones, and they are generally referred to as the migrant forms. Toward the close of the season, a brood of males and females is produced. After mating, the female lays a few rather large eggs, usually on rose bushes, if they grow in the locality, and thus they complete their life cycle.

The green peach or spinach aphids usually over-winter in the egg stage. In a mild climate, where succulent vegetables such as spinach, cabbage or kale continue growth throughout the winter, there is a constant succession of broods. As a rule, however, the

FIG. 176.—Potato aphids on under side of the leaves, natural size. (Conn. Sta.)

winged broods of aphids migrate to the peach or plum tree during the autumn and there the females deposit their eggs. In the spring these eggs hatch out, and from thence on the method of reproduction is similar to that of the pink and green louse, except that the first few generations live on the juices of the peach or plum tree, after which they migrate to a large number of other plants, of which spinach and the potato are good examples.

Remedial Measures.—As plant lice are sucking insects it is necessary to employ contact insecticides to destroy them. Lack of success in the control of the plant louse is largely due to failure to spray sufficiently early in the season. In fact, if wild roses or cultivated ones occur in the locality, the first step in the control of the pink or green louse is to destroy these plants and the peach and plum trees before the eggs hatch; or else thoroughly spray them, while still dormant, with a lime sulphur solution to destroy the eggs; or a later spraying, when the "stem mother" first hatches out, with a nicotine or kerosene emulsion solution. The destruction of the early broods is the key to their control. If these earlier precautions are not taken, a careful watch should be kept of the plants for the first appearance of the aphids in order to insure spraying, before they become so numerous, and so well ensconced on the under side of the leaves as to make it difficult to reach them with spraying materials. A proprietary nicotine sulphate compound,

Fig. 177.—Potato aphids on the tip of a growing shoot. A favorite feeding ground. (Maine Sta.)

Fig. 178.—Four-lined leaf-bug and the injury it causes to the potato leaf. Leaves reduced. Bug about natural size A. (Conn. Sta.)

known as black-leaf No. 40, is generally considered one of the most convenient and effective contact insecticides. A well made kerosene emulsion solution is regarded by some as more effective, provided it is well applied. Failure to get good results from the sprays is very often due to the inefficient application of them. A good power sprayer carrying a pressure of from 175 to 250 pounds per square inch and two or three nozzles to the row, so adjusted as to spray the under as well as the upper side of the foliage, is necessary to effectively control the aphids. It is desirable, when the plants are large and the foliage heavy, to attach a device, in the shape of a drop rod, to the rear of the spray machine, but in front of the spray boom for the purpose of bending over the tops of the plants, thus making it possible to spray the under side of the foliage. By slipping a larger rod over the rigid one of sufficient size so that it will roll on it, the injury to the foliage caused by brushing the plants over will be very materially minimized. Directions for the use of spray materials will be found in Chapter XVII.

THE FOUR-LINED LEAF-BUG

Life History.—The four-lined leaf-bug, *Poecilocapsus lineatus*, Fabr., is only an occasional pest of the potato plant. According to Britton,[4] it lays its eggs on the soft tender stems of the currant, and doubtless other plants, about the first of July, in Connecticut. The eggs are long and slender, somewhat curved, and are crowded together in clusters of six or eight, pushed endwise into the soft pith. These eggs do not hatch out until the following May. The newly hatched insects first attack the tips of the stems and the young tender leaves. They suck out the green pulp from the under side of the leaves, causing roundish, semi-transparent spots which often coalesce (Fig. 178). As insects increase in size, larger areas are involved, until the leaf turns brown, and dies. The nymphs at first are bright-red, marked with black spots, but they soon change to bright orange-yellow. They pass through five stages of development in about three weeks and when mature, are winged, nearly one-third of an inch in length, bright greenish-yellow in color with four black stripes running lengthwise on thorax and wing covers (Fig. 178).

Remedial Measures.—Spray plants with same materials as were recommended for the potato aphids.

THE POTATO LEAFHOPPER

Occurrence and Injury Caused.—While the potato leafhopper *Empoasca mali* was originally described by Le Baron in 1853 as injurious to fruit trees in Illinois, it has since been found that it also feeds on many other field and truck crops. In 1896, Osburn[16] mentioned it as being injurious to potatoes in Iowa. Twelve years later, Gibson[11] records similar observations regarding its injuriousness to the potato crop at Ottawa. Ball[1] (1918) was the first observer to call attention to the possibility of the leafhopper being responsible for some of the injury heretofore called "tip-burn." He, in fact, is inclined to the opinion that this insect causes a specific infection similar in many respects to that transmitted to the leaves of beets by the beet leafhopper. Ball has classified the foliage injury caused by the leafhopper as "hopperburn," in contradistinction to the term "tip-burn" under which all burning of the foliage, outside of that caused by arsenical poisons, has heretofore been known. In this connection he says (1919, p. 150): "It seems probable that a considerable amount of the injury referred to as 'tip-burn,' in the past, has been due to the leafhopper. On the other hand, there are, no doubt, other causes of the burning of the foliage, and it will be one of the problems of the future to differentiate these factors."

Description.—The adult leafhopper is a pale green insect about one-eighth of an inch long with wings that fold over the back. The nymphs, or immature forms, are wingless (Fig. 179). Both are very active and jump or fly away on the slightest disturbance. The adults are, of course, the more active on account of their being able to fly.

Life History.—The leafhoppers pass the winter in the adult stage hidden beneath weeds and other rubbish, and appear in the spring when they deposit their eggs. Ball[1] says (1919, p. 152): "The adults flying in the spring at the time the early potatoes come up, laid their eggs in the stems and mid-ribs of the leaves." Ruggles and Graham,[19] on the other hand, say that they do not usually make their appearance on the potatoes until late June, when the adults lay eggs on the stems. This may be true with respect to the late potato crop, but it can hardly apply to the early crop, as their date of appearance must be considerably earlier. The eggs are deposited in a longitudinal or transverse slit in the tender tips of the shoots or the mid-ribs of the leaves. They soon hatch out, and the wingless nymphs begin at once to suck the juices of the plants and reach maturity in about a month. During this period the nymphs cast their skins five times. They usually feed on the under side of the leaf where it is difficult to reach them with contact insecticides (Fig. 179). Two broods of leafhoppers are produced during the season; the first one appears in June, and the second one about August 1.

Description of the Injury.—Ball[1] (1918 p. 98) describes the injury as follows: "The first appearance of injury differs slightly

Fig. 179.—Leaf hoppers (Empoasca mali) on potato leaf. (Dr. E. D. Ball, Iowa Sta.)

in the different varieties and varies also with the number of insects and whether they are in the nymph or adult stage. In certain varieties, the leaves appear to curl up slightly before any burning appears......The first sign of trouble is usually a triangular area at the tip of the leaf, running back on the mid-rib. This is quickly followed by a progressive burning of the margin, usually from the tip backwards, but occasionally in more or less triangular spots appearing along the margin, each one of these centred in a lateral veinlet. These increase in area and the burnt margin increases in width until nothing but a narrow strip along the mid-rib remains green and, in serious cases, this weakens and dies and the leaf shrivels up.

"In practically all cases, it will be observed that the burning extends farther along the mid-rib and the lateral veinlets than it does on the membrane of the leaf. A further examination will show that these veins and veinlets are badly distorted by punctures and usually shrivelled and collapsed for some distance back of an apparent injury. In many cases, it will be found that an egg deposited transversely across the mid-rib just back of the triangular spot at the tip was responsible for the collapse of this structure

Figs. 180 and 181.—Tubers infested with eelworms.

and the consequent death of the triangle at the tip." Ball (*l.c.* p. 79) draws the following distinctions between tip-burn and hopperburn: "On leaves of different plants, where no insect agency was apparently present......it was observed that the burning appeared to affect the membrane of the leaves and to avoid the mid-rib and veinlets; while hopperburn appeared first on the veinlets, and spread later to the area of membrane which they supplied."

Amount of Injury.—While it is very difficult to estimate the amount of injury to the potato crop, as a result of leafhopper attacks, it is safe to say that when these insects are abundant they very materially lessen the yield. In some fields of both early and late potatoes, observed by the writer in 1919, the indications were that the yield had been reduced fully 50 per cent.

Remedial and Preventive Measures.—As the leafhopper is a sucking insect, the same remedies should be used in combating it as those suggested for the pink and green aphids, *viz.*, nicotine sulfate or kerosene emulsion, and the same thoroughness of application is necessary to get even fair results. The leafhopper being such an active insect, hopping or flying away on the slightest

FIG. 182.—Tubers badly infested with eelworms.

disturbance, is more difficult to destroy than is the potato aphid. The best preventive measure is secured through keeping the plants well covered with Bordeaux mixture. The mixture serves as a repellent to the insect by rendering the foliage distasteful to it.

THE EELWORM DISEASE

Among the many parasites of the potato the eelworm or nematode, *Heterodera radiciola,* is one of the most interesting. It is an animal parasite which lives upon the juices of the host plant infested. It attacks many members of the vegetable kingdom, among which is included the potato. Thus far, it has caused greater injury to the potato crop in certain portions of California, Nevada, Texas, Florida, and the South Atlantic States as far North as Virginia, than in other localities. It has a rather wide distribution in the warmer portions and lighter soils of the South.

Description of the Injury.—The presence of eelworms in the potato crop may be detected from the general appearance of the roots and tubers of the plant. Roots that have been invaded by the eelworm are almost certain to have well-developed knots or enlargements, and the surface of the tubers will be more or less disfigured by pimply or wart-like developments, (Figs. 180 to 182), depending upon the severity of the attack. It is quite possible to mistake these pimply growths for those caused by the larvæ of the

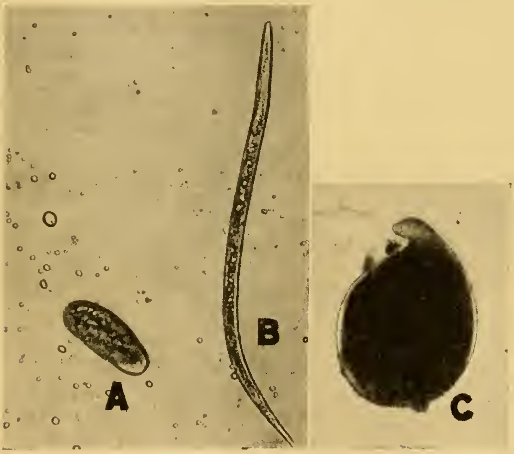

Fig. 183.—Photographs taken through the microscope of three stages in the development of the eelworm which affects the potato. (A) An egg which contains a young coiled eelworm or larva enlarged 185 times. (B) A larva at the same magnification. It is in this stage that the eelworms penetrate the roots and tubers of the plants. (C) A matured, pear-shaped female enlarged about 25 times.

flea beetle. The only way by which the two can be certainly identified is by an examination of the tissue of these growths; if they are caused by the eelworm, the white, glistening, pear-shaped bodies of the mature female will be noted; (Fig. 183 c) whereas, if caused by flea beetle larvæ, only dead vegetable tissue will be observed.

Life History of the Eelworm.—According to Byars,[5] "there are three readily recognizable stages in the life history of this eelworm, or as it is more commonly known, nematode; namely, the egg, larvæ, and adult (Fig. 183). Only the adults are visible to the naked eye." The newly hatched larvæ escape into the soil, seek the underground portions of the plant stem, roots or tubers, penetrate them and once within, develop into the adult stage. After the mating of the males and females, the former soon die. The females remain in the host tissue, and are capable of laying large numbers of eggs which, in turn, give rise to another generation of larvæ, thus completing the life cycle.

Preventive Measures.—Serious injury to the potato crop may be largely avoided through the observance of certain precautionary measures. In the first place, eelworm-infested tubers should never be used for seed purposes; use only clean seed. Practise at least a three- or four-year rotation on land known to be infested with eelworm. Use rotation crops that are resistant to them, such as velvet beans, beggar weed, and certain resistant strains of cowpeas.* By such practice, the eelworm may be largely exterminated through starvation. Clean cultivation of these crops is necessary to the successful starving out of the eelworm, as the weeds, if permitted to grow, might serve as host plants for this pest.

QUESTIONS ON THE TEXT

1. To what extent do these pests injure the potato crop?
2. Into what two general groups may these pests be divided?
3. Name the four classes into which the two groups are divided?
4. To what group does the Colorado beetle belong?
5. Give a brief history of the eastward march of the potato beetle?
6. What is its life history?
7. How is it controlled?
8. Describe the potato flea beetle and tell of its injury.
9. How can the flea beetle be controlled?
10. Describe the three-lined potato beetle. Give its life history.
11. What remedial measures are advocated?
12. Describe the tortoise beetles and give distinguishing characters of three species.
13. What is their life history? How are they best controlled?
14. Describe the blister beetles and their injury.
15. How are they best controlled?
16. Describe the stalk-borer and its work.
17. Give its life history and control.
18. Describe the potato stalk-weevil.
19. Give its life history and control.
20. How do cutworms injure the potato? How many species attack it?
21. Give their life history and control.
22. What is the natural food of the white grub?

* For a larger list of immune or resistant crop plants see:—*U. S. Dept. Agr. Farmers' Bulletin*, 648.

23. Upon what parts of the potato plant does it feed?
24. Give life history and control.
25. Describe the wireworms and their work.
26. Give the life history and control.
27. By whom and at what date was the potato tuber moth first mentioned in literature?
28. Give its origin and distribution.
29. Describe the potato tuber moth and its injury.
30. Give its life history and control.
31. How would you deal with insect infested tubers in storage?
32. Give a common name of potato aphids. What kind of mouth parts?
33. Give its life history and control.
34. Describe the application of insecticide to the lower surface of the leaves.
35. Describe the four-lined leaf-bug and its work.
36. What remedial measures are recommended?
37. When was the apple leafhopper first regarded as a potato pest?
38. Describe it and its work.
39. What is its life history and control?
40. How may one detect the presence of the eelworm in the potato crop?
41. Give the life history of the eelworm.
42. What preventive measures can be employed?

QUESTIONS AND EXERCISES SUGGESTED BY THE TEXT

1. Name the five leading insect or animal enemies of the potato in order of their local importance.
2. Collect specimens of such insects.
3. Collect samples of injuries from such enemies.
4. What methods of control are used by local growers against the worst enemies?
5. Calculate the annual cost of such control measures on one or more farms.
6. Calculate the saving by same.

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CHAPTER XVII

FUNGICIDES AND INSECTICIDES: THEIR PREPARATION, USE, APPLICATION, AND RESULTANT BENEFITS. SPRAY EQUIPMENT AND CLASSIFICATION

General Discussion.—In previous chapters it has been clearly shown that maximum potato crops are dependent, in no small measure, upon the degree of protection given the plants against the attack of fungous or insect pests through fungicidal or insecticidal applications. In the present chapter it is proposed to give a list of the more commonly used fungicides and insecticides for the control of disease or insect enemies of the potato plant and tuber. It has been shown, in the chapter on diseases, that certain fungous pests attack both plant and tuber; that others attack only the foliage, or only the tuber; that some are controlled by spraying the plants, and others by treating the seed. In the case of insect pests, it has been noted that some are controlled by poisons; others by contact insecticides; some by poisonous gases; and still others by what we call repellents; as, for example, the presence of a good coating of Bordeaux mixture over the surface of the leaves of a potato plant serves as a more or less effective repellent against the attacks of the flea beetle and the potato leafhopper.

Group Classification of Fungicides and Insecticides.—For the sake of convenience in discussion, the fungicides and insecticides have been grouped according to their uses.

Fungicides controlling	Foliage diseases	Bordeaux mixture
		Bordeaux paste
		Dry Bordeaux
		Pyrox
	Tuber diseases	Corrosive sublimate
		Formalin solution

- Insecticides controlling
  - Leaf-chewing insects
    - Paris green
    - Arsenate of lead
    - Calcium arsenate
    - Arsenoids
    - Arsenite of zinc
    - Pyrox
    - Bug-death
  - Sucking insects
    - Nicotine sulphate
    - Kerosene emulsion
    - Whale-oil soap
  - Tuber-eating insects
    - Carbon bisulphide

Thus, we have fungicides controlling foliage diseases, and those that control certain diseases affecting the tubers. In a similar manner, there are insecticides that control leaf-eating insects; others that control sucking insects, etc.

Fungicides Controlling Foliage Diseases.—In the discussion of the fungicides controlling foliage diseases, it is proposed to devote the major portion of it to Bordeaux mixture, because it is believed to be the most important fungicide yet available for the control of the early and late blight.

Bordeaux Mixture.—The history of the origin of this fungicide is rather interesting in that it may be regarded as of accidental occurrence. The discovery that milk of lime, to which a copper salt had been added, possessed fungicidal properties was the result of an attempt on the part of certain vineyardists in the vicinity of Margaux, St. Julian, and Pauillac, France, to deter travellers in that region from molesting the fruit in the vineyards bordering the public highways. The salt of copper was added to the lime to give it the appearance of a poisonous compound. It was noted in 1882, during a severe epidemic of the downy mildew of the grape, that the foliage of the vines to which the above mixture had been applied remained green and healthy, while the leaves on adjacent vines not sprayed, or those that had received an application of milk of lime alone, were destroyed by the mildew. In 1885 Millardet,[8] as a result of experimental studies, published an article in which he gave the following directions for preparing the mixture, which was then known under the name of "bouillie bordelaise." "In 100 litres of water (26.42 gallons) dissolve 8 kilos (17.6 pounds) of commercial sulfate of copper. In 30 litres of water (7.93 gallons) slake 15 kilos (33.1 pounds) of quicklime. Add the milk of lime to the copper sulfate solution and stir it well." This mixture, in the absence of spray equipment such as we now have, was applied to the foliage by means of a small whisk broom. Such was the origin of the fungicide now so widely known as Bordeaux mixture. The name it now bears must have soon replaced that of "bouillie bordelaise," as it was known in this country as Bordeaux mixture in 1889. The formula in general use in 1889 and 1890 called for 6 pounds of copper sulfate and 4 of quicklime to 22 gallons of water. Bordeaux mixture of this composition was made by the writer and applied to potato plants with a watering can in 1890. A single application of this mixture, in the latter part of the growing season, was sufficient to thoroughly protect potato foliage against a severe epidemic of late blight, which completely destroyed unsprayed plants.

The present standard Bordeaux mixture formula for potatoes is known as the 5-5-50; that is, 5 pounds copper sulphate, 5 pounds lime and 50 gallons of water. In regions where late blight is of infrequent occurrence, or in seasons when the climatic conditions are unfavorable to its development, a 4-4-50 Bordeaux will give satisfactory results. In fact, some pathologists now favor the weaker mixture, but it is believed that material of this strength will not so effectively control late blight as will the 5-5-50 formula.

Preparation of Bordeaux Mixture.—Although the preparation of Bordeaux mixture is comparatively simple, it is surprising how often it is improperly made; this, too, in spite of the fact that practically every Experiment Station and farm paper in the country has published detailed instructions as to how it should be made. The reason for this failure to observe the prescribed rules is, we believe, due to a lack of appreciation of the fact that good, bad and indifferent Bordeaux mixture can be manufactured from the same ingredients. A thorough understanding of what constitutes good Bordeaux mixture, and what details are necessary to observe in order to secure it, is the first essential to success. A good Bordeaux mixture is one in which the precipitate formed by the copper salt and the lime is in a very finely divided or flocculent condition. The question may be asked: What has the fineness of the precipitate got to do with the quality of the Bordeaux mixture? The answer is that the more finely divided the particles constituting the precipitate, the longer will they remain in suspension in the liquid, and the more evenly and more completely will they cover the foliage of the potato plant. A bad Bordeaux mixture is one in which the precipitate is in the form of coarse particles which quickly settle to the bottom of the spray tank, unless the material is kept in a constant state of agitation, and which has a tendency to clog the nozzles and to spread unevenly over the surface of the leaves.

Three Steps in Making Bordeaux.—The next problem confronting us is, how to make good Bordeaux mixture. Practically all directions that have been published concerning the making of Bordeaux mixture, if adhered to closely, will insure a good Bordeaux mixture. Let us see what the successive steps are in the manufacture of Bordeaux mixture. (1) In the first place, we are instructed to weigh out 5 pounds of copper sulphate, if a 50-gallon spray tank is to be used, or 10 pounds if a 100-gallon spray tank is available. The crystalline copper sulphate, or blue vitriol as it is often called, is to be dissolved in water, say 20 gallons, in a wooden vessel; an earthen vessel may be used, but never a metal one as the copper corrodes the metal. The crystals may be more quickly brought into solution by using a small volume of hot water, or by enclosing them in a coarse sack or piece of cheesecloth and suspending them in the upper surface of the water. (2) Weigh out an equal quantity of quicklime or slightly more of the hydrated lime, and slake it in a separate vessel, using just enough water to make a thick paste when slaked; then add sufficient water to make 20 gallons. (3) The copper sulphate solution and the milk of lime should then be simultaneously poured together in a third vessel, thoroughly stirred and made up to volume (Fig. 184), in this case to 50 gallons. The fineness of the precipitate is directly dependent upon diluting the two ingredients, then pouring them together at about the same rate into a third vessel and thoroughly stirring the mixture.

Bad Bordeaux mixture or one in which the precipitate is in the form of coarse particles, is the direct result of pouring the two ingredients together in a concentrated form, or by pouring the one into the other without proper dilution. The worst mixture seems to result from pouring the undiluted copper solution into the milk of lime. Many growers make a practice of putting the concentrated copper solution into the spray tank and then adding the milk of lime to it, after which they add the necessary water to bring it up to the required volume. This is a bad practice and should be unequivocally condemned. Practically all improperly

Fig. 184.—Bordeaux mixture is made by making the two stock solutions separately and then pouring the two together as shown. (U. S. Dept. of Agriculture.)

made Bordeaux mixture is the result of an attempt on the part of the grower to economize on equipment, as, for example, a few 50-gallon barrels. It is believed that, even from the labor-saving standpoint, this is a false economy; and there certainly can be no question about the wisdom of such a procedure when it results in the manufacture of inferior mixture. The object of introducing the above discussion is not for the purpose of decrying labor-saving methods, or the desirability of eliminating all unnecessary equipment, but rather to remind those who are disposed to adopt shortcuts that there is such a thing as a wasteful economy, a saving of pennies at the expense of dollars, which results in loss rather than in gain. The operator should believe fully in the adoption of all methods that make for the elimination of waste effort, and which, at the same time, produces a high grade Bordeaux mixture.

System in the Work.—One of the most efficient labor-saving devices in the manufacture of Bordeaux mixture is that of the spray mixing platform, and the stock solution barrels. The following description is one which the writer prepared for the *Seventeenth Annual Report of the Vermont Agricultural Experiment Station* for the years 1903-04, p. 440-442:

FIG. 185.—Spray mixing platform at the Vermont Experiment Station showing operation of filling spray barrel. Barrels in rear of upper platform contain the stock solutions, those in the front are the dilution barrels while the one with the strainer is the mixing barrel.

"The horticultural department has devoted considerable attention, during the past two seasons, to simplifying the labor of making Bordeaux mixture. Two objects were in view: (1) To avoid lifting, so far as practicable. (2) To promote the formation of a fine precipitate, and, therefore, of a perfect mixture.

"**A Gravity System.**—To obviate the necessity of lifting the mixture, when filling the spray pump barrel, a lean-to shed was used to serve the purpose of a temporary support to a two-tier stage or platform, (Fig. 185). On the upper platform were disposed the barrels, which were intended for stock solutions of lime and copper sulfate, and, also, those in which these solutions were to be diluted, preparatory to mixing in the third vessel on the platform below. These dilution vessels were provided with good sized faucets which were brought sufficiently close together to allow the liquid, flowing from both at the same time, to be caught in a spout which emptied into the barrel on the lower level. The two solutions, simultaneously flowing into this spout, form Bordeaux mixture during their flow along the spout; the precipitate, being extremely fine, passes through the cheesecloth strainer stretched over the top of the barrel. The contents of the mixing vessels were, in turn, transferred to the spray tank through a pipe, connected with the lower part of the barrel and extending, at right angles to it, over the spray tank, and being directed into it by means of a short ell. The flow of the Bordeaux mixture through the pipe was controlled by means of a brass valve. In this way, a perfect mixture is

Fig. 186.—A spray mixing platform and equipment used by the U. S. Dept. of Agriculture at Honeoye Falls, N. Y. The only lifting necessary with this outfit was that involved in transferring the stock solutions to the mixing barrels.

obtained, since the reaction takes place in the short spout and on the strainer, and is continued in the mixing barrel and in its transfer from it to the spray tank, where it passes through a brass strainer before flowing into the sprayer (Fig. 185). Where flowing water is available, the only lifting involved with such a platform and supply of barrels is that of transferring the necessary volume of the stock solutions to the dilution barrels; the remaining operations being all accomplished by gravity, except that the water used for diluting the stock solutions, flows into them under pressure. On a mixing platform, constructed at a later date, the water supply was obtained by gravity from a storage tank mounted on an upper bench of the platform. The storage tank, in this case, was filled from a well beneath by a power pump (Fig. 186).

"**Stock Solutions.**—Much valuable time may be saved by maintaining a constant supply of stock solutions on hand. Stock solutions are highly concentrated solutions of copper sulfate and lime kept in separate vessels. They are usually made so that each gallon of the solution represents a pound of the ingredient of which they are composed; hence, if one wishes to make up 50 gallons of Bordeaux mixture, he takes 5 gallons from each stock vessel and pours them into the dilution barrels—this will represent the amounts called for in the 5-5-50 formula. Stock solutions may be made that represent 2 pounds of copper sulfate or lime per gallon, or in the case of the copper sulfate, one may make what is known as a saturated solution, that is, one to which an excess of the copper salt has been added. A gallon of such a solution is said to contain somewhat less than three pounds of the copper salt. Owing to the fact that a gallon of the saturated solution represents two and a fractional part of a pound, and therefore is less easily measured out, it is not recommended. A saturated stock solution has one advantage over an unsaturated one in that it is not necessary to account for the moisture lost through evaporation, as is the case with the latter. Losses occurring in the less concentrated stock solutions may be rectified by marking the height of the solution in the barrel when through spraying, and bringing it up to this mark when spraying is resumed. Stock solutions may be kept almost indefinitely, but it is never advisable to hold over unused Bordeaux mixture; it should always be freshly prepared. Another precaution to be observed is to always thoroughly stir up the stock solutions before measuring out the quantities required in making a fresh lot of Bordeaux mixture. This precaution is especially pertinent in the case of the lime, as severe burning of the foliage is certain to result if only the clear lime-water liquid is taken to make Bordeaux mixture."

Application of Bordeaux Mixture.—Maximum results from properly made Bordeaux mixture can only be obtained under the following conditions:

1. Its application at the proper time.

2. Its application under sufficient pressure and through properly constructed spray nozzles, so as to give a fine, even distribution of the spray material.

3. Applications sufficiently often to keep the new foliage thoroughly covered.

4. Use poison with the mixture when it is desired as an insecticide as well as a fungicide.

It is difficult to lay down any fixed rules as to the proper time to spray except in a rather general way. In localities where late blight is common and usually prevalent, it is a good practice to begin spraying as soon as the plants are from 8 to 10 inches high. This is usually sufficiently early to arrest the development of early blight and to afford some measure of protection against flea beetle injury by serving as a repellent. Subsequent spraying should be frequent enough to keep the new growth well covered with the fungicide. When the weather is dry and hot, the sprayings may be less frequently made than when the opposite conditions prevail.

Bordeaux Paste.—Bordeaux paste is a commercial Bordeaux mixture product from which the excess moisture has been removed; it is offered to the trade in various sized packages up to a large sized keg. All that is necessary to convert it into a Bordeaux mixture is to add the required amount of water. It is not as efficient in the prevention of late blight as is fresh, home-made Bordeaux mixture when properly made. This is largely due to the fact that the Bordeaux paste forms a coarser precipitate, and consequently gives much the same result as the poorly made Bordeaux mixtures previously described.

Dry Bordeaux contains the copper sulfate and lime in a dry, powdered form, and is intended to be applied as a dust. Bird[2] recommends the following method of preparing dry or powdered Bordeaux. Dissolve 10 pounds of copper sulfate in 4 gallons of hot water. Slake 5 pounds of quicklime in 4 gallons of water. Slake remaining lime (full barrel minus the 5 pounds) to a perfectly dry dust. Pour the copper and the milk of lime solutions together, simultaneously, into a third vessel, and stir until no greenish streaks appear; then distribute the mixture over the lime dust and mix with a rake. While still somewhat damp, rub it through a sieve and spread out to dry. This requires a day or two, after which the mixture will keep indefinitely. These quantities make about 200 pounds of powder.

Commercially prepared Bordeaux powder is a regular article of commerce, but as yet it has not come into much favor in potato spraying. This statement should not, however, be taken as a final verdict in regard to the use of Bordeaux powder as a fungicide for the potato crop. The constant improvement that is being made in dust spray equipment has made these fungicides much more effective in the control of plant diseases. Dust sprays adhere best when applied in the early morning or late evening, when the foliage is moist with dew.

Pyrox is a proprietary compound possessing both fungicidal and insecticidal properties. It is a more expensive fungicide than Bordeaux mixture, and does not give quite as good results as the fresh, properly prepared, home-made Bordeaux. The heavier initial cost of Pyrox is, to some extent, offset by the fact that it is immediately available for use upon the addition of the required volume of water, and, in addition, contains sufficient poison to serve as an insecticide. Use at the rate of 10 pounds to 50 gallons of water.

Bug-Death.—The manufacturers of bug-death claim that it is an effective fungicidal and insecticidal compound; but wherever it has been carefully tested it has not fully protected the foliage from late blight, in fact it only gave slight protection. When used liberally, it does control leaf-eating insects. It is too expensive to use as an insecticide, at least in commercial fields.

Fungicides Controlling Tuber Diseases.—It is realized that this caption is rather misleading since there are tuber diseases that cannot be controlled by fungicides. It is hoped, however, that its use in this connection may be justified on the basis of conformity to the other terms employed; as, for example, fungicides are employed as disinfectants, their function being to destroy the fungous organisms causing common scab, and the black scurf or rhizoctonia; also to destroy other spores, particularly those of blackleg, which may be lodged on the outer surface of the tuber. The function of these fungicides ceases with the destruction of such organisms as have been mentioned, which occur on the seed tuber itself. If the disinfected tubers are planted in soil free from the organisms of common scab or of rhizoctonia, the resultant crop of tubers should be free from these two diseases; but if the soil is infected, the new tubers are also likely to be infected. Treatment of the seed tubers, therefore, simply destroys the organisms of these diseases upon the surface of the tuber. It is a guarantee of a clean crop only when the land in which they are grown is free from infection.

Corrosive Sublimate Treatment.—Corrosive sublimate was the first fungicide to be successfully employed in the disinfection of seed potatoes of the disease known as the common scab. It was first successfully employed by Dr. H. L. Bolley, of the North Dakota Experiment Station, when connected with the Indiana Experiment Station in the late eighties.

The formula recommended for potato scab and rhizoctonia disinfection is as follows: Dissolve 4 ounces of corrosive sublimate (Mercuric chloride, $Hg\ Cl_2$) in a small quantity of hot water in an earthen, porcelain or wooden vessel and dilute to 30 gallons of water. Hot water is suggested as a solvent, because mercuric chloride dissolves very slowly in cold water. In many instances the indifferent results that have been secured from corrosive sublimate treatment have been due to the fact that the crystals or powder have not gone into solution, hence it was too weak to be effective. Be sure that the material all goes into solution. The quickest way to dissolve it is to place the porcelain vessel containing the crystals and the water over a free flame or on a hot stove, and let it come to a boil.

In the use of corrosive sublimate it should be remembered that the substance is a deadly poison. Every vessel, therefore, with which the solution has come in contact should be thoroughly cleansed before using it for other purposes, and every precaution should be taken to prevent accidents through the drinking of the solution by farm animals. All discarded material should be so disposed of as to quickly disappear in the ground. An ounce of prevention is better than a pound of cure.

The period of treatment of the seed tubers in the corrosive sublimate solution varies with the condition of the seed. If the seed stock is free from the sclerotia or resting bodies of rhizoctonia and comparatively free from common scab, an immersion of one-half hour will be sufficient. If the tubers are badly germinated, the period of treatment should be cut down to a half hour to avoid serious injury to the new sprouts. Where there is considerable rhizoctonia infection and the tubers are dormant, a treatment of one and one-half to two hours is advisable. As soon as the tubers are treated they should at once be spread out to dry. It is always advisable to treat seed stock before cutting it.

Recent investigations have shown that the strength of corrosive sublimate rapidly decreases with each lot of treated seed. It is now suggested that not more than three lots be treated in the same solution without reinforcing or renewing it (Figs. 187 and 188).

Formalin Treatment.—Formalin is a trade name applied to a 40 per cent solution of formaldehyde gas. It is a non-poisonous, colorless liquid, much more easily handled than corrosive sublimate and practically as effective in combating scab; but it does not seem to have the same penetrative power as corrosive sublimate when it comes to destroying the resting felt-like bodies (sclerotia) of rhizoctonia.

It was first employed as a remedy for potato scab by Dr. J. C. Arthur, botanist of the Indiana Experiment Station. The actual experimental studies determining the best strength of solution to use, and the most satisfactory period of treatment were worked out by the writer, under the direction of Dr. Arthur, during the winter of 1895-96.[1] Badly scabbed tubers were treated in formalin solutions of 1 to 200, 1 to 400, and 1 to 800 strengths and the tubers grown in sterilized soil in a small greenhouse connected with the botanical laboratory. The 1 to 200 strength was the only one that gave clean progeny. The formula now used, 1 pint to 30 gallons of water, is approximately 1 to 240.

Period of Treatment.—The period of treatment usually recommended is one and one-half to two hours; but recent studies have demonstrated that a much shorter period, one-half to one hour, is

Fig. 187.—Treating seed potatoes with corrosive sublimate solution. The use of the slat crate as a receptacle is a time saving proposition because the potatoes will dry off in the crates after their removal from the solution. It also prevents re-infection through their coming in contact with an unclean package. Courtesy of Daniel Dean, Nichols, N. Y.

satisfactory. The shorter period should be used when the tubers to be treated are germinated. When they are dormant and have much scab or rhizoctonia infection, immerse the seed from one and one-half to two hours. After treating the tubers spread them out to dry.

Insecticides Controlling Leaf-chewing Potato Pests.—It is well known to every potato grower that the leaf-chewing insects are more easily controlled by insecticides than the sucking insects. This is due to the fact that they are readily destroyed by the application of poisonous substances to the foliage. Arsenical poisons are chiefly employed in the control of leaf-chewing insects. The poisons most commonly employed are Paris green, arsenate of lead, arsenoids, calcium arsenate, arsenite of zinc, pyrox and bug-death.

Paris Green.—The insecticide so widely known under the name of Paris green is a precipitate of white arsenic and acetate of copper (*verdigris*). It may be prepared by making a boiling hot solution of each of these two substances in separate vessels, and then pouring them together, whereupon the substance we know as Paris green is precipitated in the form of a very fine, clear, green powder. Its value as an insecticide is due to its arsenical content. Nearly all of the arsenic it contains is insoluble in water. Paris green may be applied as a liquid or a dust spray (Fig. 189). When applied as a liquid spray, it should be used in connection with

Fig. 188.—Treating seed potatoes on a large scale in a corrosive sublimate solution. Tank filled with 165-pound sacks of potatoes. In this case heavy lifting is avoided by use of pulley blocks. Platform at rear of tank is used as a draining board when sacks are removed. Caribou, Me., 1914.

milk of lime equal to 2 pounds of lime to 50 gallons of water, or in Bordeaux mixture to guard against injury to the foliage from the slight amount of free arsenious acid that may be present. It should be used at the rate of 8 ounces to 50 gallons of water. If the insects are abundant and the poison can be added to Bordeaux mixture, it may be used at the rate of a pound to 50 gallons, without risk of injury to the foliage.

The dry powder is most conveniently brought into suspension in water by first making a paste of the Paris green. This is very quickly accomplished by placing it in a small vessel, and adding just enough water to thoroughly moisten the whole mass. Through constant stirring it is soon brought into the condition of a paste, in which state it readily mixes with water. When used as a dust spray, it should be mixed with some neutral substance, such as air-slaked lime, land plaster or any other powdered material which will act as a carrier of the poison. There is no generally accepted formula concerning the rate of dilution of the dry form; in fact, the recommended rates vary from 1 pound of Paris green in 19 pounds of the diluent to 1 pound in 99 pounds—with

FIG. 189.—Applying a dust spray of Paris green and air-slaked lime to the young potato plants to protect them against the ravages of the Colorado potato beetle or the flea beetle, either or both of which may cause serious injury to the plants just after they appear above ground.

all the intermediate strengths. Very good results have been obtained when diluted to 1 in 30 parts. Occasionally, growers are found who apply dry Paris green without diluting it. In such cases, it is applied with hand atomizers which deliver a very fine dust. It has been used in this way at the rate of from 5 to 6 pounds per acre with but slight injury to the foliage. Such practice is both wasteful of the insecticide and dangerous to the health of the plant, and should never be recommended. Diluted with lime or other carrier and applied with a dust spray gun, when the foliage is moistened with dew in the early morning or late evening, it adheres well to the foliage, and is effective in destroying the leaf-chewing insects.

Arsenate of lead is a precipitate formed by the admixture of solutions of arsenate of soda and acetate of lead. Forbush and Fernald[5] published the following statement concerning arsenate of lead:

"Although nearly all poisons known to us which can be used as insecticides have been experimented with during the past five years, in the hope that something would be found which would prove fatal to the gypsy moth, only one which is more effective than Paris green has been discovered. This is arsenate of lead, a poison slower in its action than the other, but which has three distinct advantages: (1) It can be used at any desired strength without serious injury to the foliage. (2) It is visible wherever used, as it forms a whitish coating on the leaves. (3) It has adhesive qualities, given it probably by the acetate of lead, and therefore remains on the leaves for a much longer period than Paris green."

The formula used by the commission in making their arsenate of lead consisted of 30 parts of arsenate of soda and 70 parts of acetate of lead. Fernald further suggests that it may be prepared in the proportion of 11 ounces of acetate of lead to 4 ounces of arsenate of soda. Both substances are brought into solution in separate vessels, and then poured slowly together into a third, the precipitate thus formed being the arsenate of lead.

Arsenate of lead is now commonly offered to the trade in the paste and in the dry or powder form. The paste is a little more convenient to use, as it is readily diluted with water to the desired strength. Its selling price per pound is less than the dry form, but a much greater amount must be used in order to secure the same effectiveness, which makes it, in reality, somewhat more expensive than the powder form.

In order to be effective against potato insects, arsenate of lead paste must be used at the rate of 3 to 5 pounds in 50 gallons of water. In the dry form, 2 to 3 pounds is sufficient.

The difficulty of mixing the dry arsenate of lead with water may be overcome by wetting the mass. Then stir into a thick paste before diluting.

Calcium Arsenate.—This relatively new arsenical insecticide is being used as a substitute for arsenate of lead or Paris green to control the potato beetle. The manufacturers claim that it contains more arsenic than the arsenate of lead powder, and that, in consequence, three-quarters of a pound of it is equal to one pound of the arsenate of lead powder. When used alone as a liquid spray, it is recommended that an equal amount of hydrated lime be used with it. Use at rate of one and one-half to two and one-half pounds to 50 gallons of water or Bordeaux mixture.

Arsenoids.—In some sections of the country and particularly in Aroostook County, Maine, arsenoids have been used very extensively in combating the potato beetle. There have been offered to the trade, at various times, preparations known as white arsenoid, pink arsenoid, green arsenoid, etc. Morse[9] describes these arsenoids as follows:

"White arsenoid was supposed to be barium arsenite, but all of its arsenious acid was free, so that it was no better than white arsenic diluted with baryta. Pink arsenoid is arsenite (not arsenate) of lead. The green arsenoid or arsenite of copper, if pure, would carry about 53 per cent of combined arsenious oxide."

Other arsenoids under numbers 2, 3, 4 and 5 are discussed, and the author summarizes the results of his experiments with these insecticides in the following statements:

"There was not much difference to be seen in the way the different arsenoids acted. None of them, at the rate used, burned the foliage; and they all killed the insects practically as well as Paris green. The arsenoids are more bulky, and on this account are more readily kept in suspension than Paris green. The field notes show the arsenoids to have been about as effective as Paris green, but not so effective as arsenate of lead."

Arsenite of zinc is a compound of zinc and arsenic, and is not so well known as the arsenate of lead, as it is a newer compound. It is one of the most effective insecticides. It is a whitish precipitate or powder that readily mixes with water. The adhesive properties of arsenite of zinc are as good, if not better, than that of the arsenate of lead. Used at the rate of 2 pounds to 100 gallons of water it has proven as effective as much larger amounts of arsenate of lead, but it is somewhat more expensive per pound. It is readily mixed with water, stays in suspension well, and never causes any burning of the foliage.

Pyrox.—As previously noted under fungicides, pyrox is a combination fungicidal and insecticidal preparation, and should never be used except when intended to control fungous diseases as well as insect pests.

Insecticides Controlling Sucking Insects.—Sucking insects are provided with a strong beak or proboscis which they insert into the tissues of the plant and remove its juices. It is evident, therefore, from the manner in which they secure their food supply, that arsenical poisons are not effective against this class of insect enemies of the potato. In order to successfully combat sucking insects, it is necessary to employ what are commonly known as contact insecticides, that is, insecticides that will kill by direct contact through corrosive action, or through a volatile oil. Volatile oil compounds are not ordinarily employed in spraying potatoes, hence they are not considered in the present discussion. The commonly employed insecticides are nicotine sulfate or black-leaf 40, kerosene emulsion, and whale-oil soap.

Fig. 190.—A type of sprayer called atomizer. (School and Home Gardening.)

Black-leaf 40 is a proprietary compound of nicotine sulfate, a powerful narcotic poison. In color and general physical properties it very much resembles a low grade, black-strap molasses. It may be used at the rate of 1 pint to 50 gallons of water. On account of the ease with which black-leaf 40 can be prepared for use, it has become a very popular insecticide for the control of the potato aphid and other sucking insects.

Kerosene Emulsion.—Although kerosene emulsion is one of the oldest of our home-made contact insecticides, it is not very generally employed. This, I believe, is due to the difficulty that most people encounter in the preparation of an emulsion from which the oil does not separate. Various formulas have been suggested from time to time for its preparation. In general, these formulas differ only in the quantity of soap to use. For example, "Cook's hard soap emulsion" calls for one-quarter of a pound of hard soap such as Ivory, Babbitt, etc., dissolved in two quarts of boiling water, to which is added one pint of kerosene oil. The oil and soap solution is emulsified by pumping it back and forth with a hand pump while it is hot, until a perfect emulsion is obtained. This emulsion is diluted with twice its volume before using.

The Hubbard-Riley Kerosene Emulsion calls for the following amounts:

Hard soap .... ½ pound
Kerosene.......................... 2 gallons
Boiling soft water.................. 1 gallon

This formula is prepared in the same way as the Cook formula. In the matter of dilution, however, the recommendations are different; this stock solution should be diluted with from 4 to 20 parts of water. The latter dilution should be used in spraying potato plants.

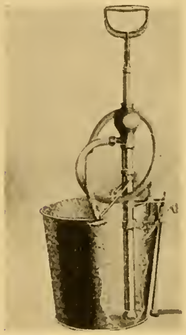

FIG. 191.—A bucket sprayer for very small patches. (Fights of the Farmer.)

FIG. 192.—Knapsack Sprayer, carried on back of the operator. (Fights of the Farmer.)

Britton[3] recommends a still different formula which he claims gave better results than those ordinarily used. This formula calls for somewhat larger amounts of soap and kerosene:

Laundry soap (about 30 ounces) .... 3 cakes
Kerosene................................ 4 gallons
Water.................................... 2 gallons

Emulsify as previously directed and dilute eight times, practically a 50-gallon barrel. Britton says: "All the aphids hit by the spray were killed without injury to the plants."

Whale-oil Soap.—The value of whale-oil soap as an insecticide for sucking insects has long been recognized. It is effective against plant lice when used at the rate of one pound to 10 gallons of water. The soap should be shaved into thin slices, dissolved in a small volume of boiling hot water, and then diluted to the required strength. Whale-oil soap may also be used in place of hard soaps in making kerosene emulsion.

Suggestions for Spraying Aphids.—The value of any of the above spray materials in the control of sucking insects is directly dependent upon the thoroughness with which it is applied. This statement is particularly true with the potato aphid which, as a rule, feeds upon the under surface of the leaf, oftentimes causing it to roll downward and inward. The spray material must be so directed as to reach and cover the under surfaces of the leaves. This can be most conveniently accomplished, when the plants are large, by suspending a rod or other device beneath but slightly in advance of the spray nozzles, and sufficiently low to drag the tops over; this exposes the lower surface of the leaves to the spray material, provided the nozzles are properly adjusted. Injury to the vines, from being dragged over in this manner, may be minimized by slipping a slightly larger pipe over the suspended rod, so as to permit a revolving motion as the plants are bent over.

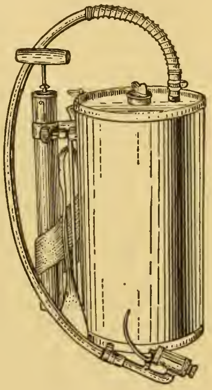

Fig. 193.—Compressed air sprayer. This type of sprayer fills about the same need as the knapsack type.

Insecticides Controlling Tuber-eating Insects.—The only insect pest of the tuber that can be destroyed by a gaseous compound is the potato tuber moth. Treatment can only be applied when the crop is in storage, and the storage house or room is sufficiently tight to hold gas for a reasonably long period. The substance used is a colorless liquid known as carbon bisulfide. Graf[6] recommends the following dosage: two pounds of carbon bisulfide to each 1,000 cubic feet of air space; expose to fumes for 48 hours. Graf says that at this strength the larvæ and adults and practically all the pupæ and eggs are killed. If the tubers are noticeably infested, the fumigation should be repeated in a week, if in summer, or in two weeks in winter. It is suggested that the liquid should be placed in shallow tin pans above the material to be treated, as the gas is heavier than air. Carbon bisulfide gas is a highly explosive compound when mixed with air, therefore, care should be exercised not to have it come in contact with a flame or spark.

Resultant Benefits from Fungicides and Insecticides.—The resultant benefits from the use of fungicides or insecticides have, so far as we are aware, only been determined in the case of the late blight. It is obvious, of course, that equally striking data might be collated with reference to the injury caused by insects, and particularly so by the potato beetle. In fact, it is conceivable

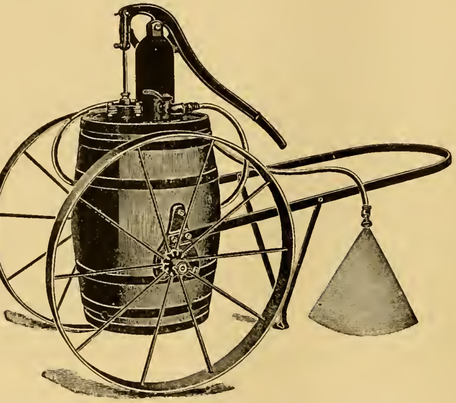

Fig. 194.—Barrel spray pump mounted on hand cart. Fairly efficient sprayer for relatively small commercial areas.

that the crop might be entirely destroyed, so far as the production of marketable tubers are concerned, if not protected from the ravages of insect pests by some arsenical application.

The most interesting data upon this subject are those published by Lutman[7] in which the author discusses the results of 20 years of spraying with Bordeaux mixture, applied to late maturing varieties of potatoes, for the control of late blight, by his predecessors in the work. These results, as summarized on page 247, represent gains from the use of Bordeaux mixture, ranging from 32 bushels per acre in 1906, to 224 bushels per acre in 1893. The total average yield per acre from the sprayed plants for the 20 years was 268 bushels per acre, and 163 from the unsprayed plants, a gain of 105 bushels per acre or 64 per cent.

At the New York State Experiment Station in a ten-year spraying test, 1902 to 1911 inclusive, at Geneva, and Riverhead, L. I., the following average increases from 3 and 5 to 7 sprayings were obtained: Geneva, N. Y., 3 sprayings resulted in an increase over unsprayed plants of 69 bushels per acre; 5 to 7 sprayings 97.5 bushels; Riverhead, 3 sprayings 25 bushels, 5 to 7 sprayings 45.7 bushels.

Many other instances might be cited where much larger gains from spraying were obtained. One of the most striking examples

Fig. 195.—The sprayer in operation. When the plants are full grown the spray boom should be raised high enough to permit of a wide and even distribution of the spray material. Presque Isle, Me.

that has come to the writer's attention of benefit derived from thorough spraying with Bordeaux mixture on a commercial scale, is reported by Dean[4] for the years 1912, 1915 and 1917. These were years in which severe epidemics of late blight rot occurred. In these three seasons Dean sprayed his crop 14, 8 and 11 times, respectively, and, as a result thereof, secured increases over unsprayed plants of 183, 200 and 213 bushels per acre. It should be said that such increases are possible only where the spraying is thoroughly done, and where cultural conditions are satisfactory to the production of a large crop.

Spray Equipment.—The development of spray equipment has practically kept pace with that of the chemist in the manufacture of new fungicides or insecticides. Broadly speaking, spray equipment may be roughly classified under two heads, *viz.,* liquid and dust sprayers. Liquid spray equipment may in turn be divided into hand, tractor, and gasoline-driven pumps. Hand equipment may consist of a hand atomizer, bucket pump, knapsack sprayer,

Fig. 196.—A two-horse traction sprayer in operation. Courtesy of Bateman Manufacturing Co.

Fig. 197.—Spray outfit hauled by horses, pump operated by a gasoline engine mounted in front of spray tank. Courtesy of Bateman Mfg. Co.

auto-spray, and barrel-pump sprayers. The tractor-driven sprayers consist of one- or two-horse machines of from 50 to over 100 gallons capacity, the pump of which is operated by being geared to one or both wheels of the spray cart. Such machines, when the valves are properly packed, are capable of developing from 125 to 200 or more pounds of pressure. Gasoline-driven spray equipment consists of spray machines hauled by horses or tractor with gasoline-operated pump. With such machines it is possible to develop from 200 to 300 pounds pressure per square inch. With such a pressure and proper nozzles the liquid spray is broken into such fine particles that it resembles a fog or fine mist. When applied in this manner, properly made spray materials are much more effective in the control of fungous or insect pests than with a pressure of 75 to 125 pounds.

Dust sprayers or blowers are receiving much more favorable attention at the present time than in the past. The manufacturers

FIG. 198.—A traction-power dust spray machine in action. Courtesy of Niagara Sprayer Co.

of dust blowers are constantly perfecting their machines and we may look forward to a much larger use of dust sprays in the future.

Spray Equipment Classification.

Liquid Spray Equipment

Hand-operated equipment	Atomizer (Fig. 190)
	Bucket pumps (Fig. 191)
	Knapsack sprayers (Fig. 192)
	Auto-spray tanks (Fig. 193)
	Barrel pumps (Fig. 194)
Tractor-operated equipment	Horse-drawn sprayers with pump operated by wheel gears (Figs. 195 and 196)
Gasoline-operated equipment	Spray machine hauled by horses or tractor; pump operated by gasoline engine (Fig. 197)

Dust Spray Equipment

Hand-operated	Atomizers
	Blow guns
	Bellows
Tractor-operated	One- or two-horse tractor-driven dust sprayers (Fig. 198)

QUESTIONS ON THE TEXT

1. How are the fungicides and insecticides grouped?
2. Give a list of the commonly used preparations for foliage diseases.
3. What are the two commonly employed fungicides used for tuber disinfection?
4. What are some of the insecticides used for the control of leaf-chewing insects?
5. What three insecticides are recommended for sucking insects?
6. What is recommended for tuber-infesting insects?
7. Give the steps in discovery and development of Bordeaux mixture.
8. What is the present standard formula for use on potatoes?
9. What constitutes a good Bordeaux mixture? A bad Bordeaux mixture?
10. Upon what does the fineness of the precipitate depend?
11. What happens when the milk of lime is added to a concentrated copper solution?
12. To what is improperly made Bordeaux mixture largely due?
13. What are the advantages of a convenient spray mixing platform?
14. What is meant by a gravity system of Bordeaux mixing? How does it help?
15. What are stock solutions? How are they prepared?
16. In what way can maximum results be obtained from a properly made Bordeaux mixture?
17. In localities where late blight is common, when should spraying begin?
18. Discuss Bordeaux paste and dry Bordeaux and their uses.
19. Compare Pyrox as a fungicide with Bordeaux mixture.
20. Is bug-death equal to Bordeaux mixture as a fungicide?
21. What fungicides are employed in disinfecting seed potatoes?
22. Give formula for the preparation of the two solutions and the time of immersion for black scurf.
23. Should the seed stock be treated before or after cutting?
24. Compare leaf-chewing insects and sucking insects in their ease of control.
25. What is Paris green?
26. How is it usually employed, and in what strength?
27. When employed as a liquid spray, what precaution should be observed in order to avoid foliage injury?
28. How may the dry powder be most readily mixed with water?
29. Give directions for mixing and use as a dust.
30. When is the best time to apply dust sprays?
31. What is arsenate of lead? How is it manufactured?
32. Compare the powder and the paste forms, and give relative amounts to use.
33. What is calcium arsenate, and how does it compare in effectiveness with arsenate of lead?
34. Compare the arsenoid insecticides with arsenate of lead in effectiveness.
35. How does arsenite of zinc compare in effectiveness with arsenate of lead?
36. How are sucking insects controlled?
37. What are the three commonly employed contact insecticides?
38. What is black-leaf 40? How used?
39. How is kerosene emulsion prepared?
40. Of what value is whale-oil soap in combating sucking insects?
41. Upon what does the value of contact insecticides largely depend?

42. What results were secured at the Vermont Station from the use of Bordeaux mixture?
43. What results were secured at the New York State Station?
44. What increases did Dean secure from spraying?
45. How may liquid spray equipment be classified?
46. Describe each group or class of spray equipment.
47. What types of dust sprayers have we?

QUESTIONS AND EXERCISES SUGGESTED BY THE TEXT

1. Make a list of combined troubles for which we should use combined sprays—insecticides and fungicides.
2. Give the combined sprays to use in each case.
3. Make a list of the diseases and insects which are likely to give trouble to local crops.
4. Make a season's spray calendar showing the troubles, remedies and times for use in your region.
5. Inquire from local growers and determine the numbers of applications of sprays for the worst enemies.
6. Make a local study to determine the degree of effectiveness of various treatments and materials tried by growers.
7. Make a collection of materials described in this chapter.
8. Make up small quantities of stock solutions of Bordeaux.
9. Make good Bordeaux, and bad Bordeaux. Compare.

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CHAPTER XVIII

INDUSTRIAL USES OF THE POTATO IN AMERICA AND FOREIGN COUNTRIES

THE value of any food crop for industrial purposes and particularly a perishable one, is largely determined by the cheapness of its production; its chemical composition; the number of valuable constituents embodied in it; the ease with which these elements may be converted into commercial products; and last, but by no means least important, the market outlet for its products.

Constituents of the Potato.—Chemical analysis of the potato shows that it contains approximately 75 to 80 per cent of water, 14 to 20 per cent of starch (occasionally this amount may reach 23 to 25 per cent), 1.5 to 2 per cent of proteins, and 2 to 3 per cent of fibre and mineral salts or ash. Its value, both as a food and in the industries, is due to its starch content. Starch occurs in many other crops besides the potato, of which the most important commercially are corn, cassava, rice, sago, arrow-root, and wheat.

Potato Products.—Thus far, the chief manufactured products consist of potato starch, potato flour, dried or dehydrated potatoes, dextrine, glucose, dextrose or starch sugar, alcohol and lactic acid. There are, doubtless, other possible uses of potatoes.

The process of starch manufacture is a relatively simple one consisting of thoroughly washing the potatoes; grinding or grating them into a fine pulp; washing the starch from the fibrous material of the potato through fine sieves; collecting it in large vats, where by changes of water the impurities are separated from the starch. The starch settles to the bottom of the vat, from whence, after the liquid has been drawn off, it is removed to the drier and subjected to heated air until the moisture content is reduced to about 18 per cent.

The requirements for starch manufacture on a commercial scale are an abundant supply of pure water, a cheap but commodious building, having a reasonable storage capacity, conveyors to convey the potatoes to the washer and grinder, sieves for separating the fibrous parts from the starch, several settling tanks of rather large capacity to purify the starch, and a drier provided with steam or flue heat for drying the starch.

The dried starch may be marketed in 200-pound sacks or 500-pound wooden casks.

Starch Yields.—The average yield of commercial starch from cull potatoes in the United States is approximately 15 per cent of the weight of the raw material, that is 15 pounds per hundredweight of potatoes, or 9 pounds per bushel. The yield from good, sound, well ripened tubers of varieties averaging 20 per cent of starch is correspondingly greater.

Uses of Potato Starch.—The uses or commercial outlets for potato starch, or in fact any starch, may be roughly divided into three classes: (1) for edible purposes; (2) for laundry purposes; (3) for manufacturing purposes.

1. Starches are used for edible purposes in puddings, confectionery, pastry, and as a stiffener for ice cream, custard, pie fillings, and in sausage and blood pudding making. For the last two mentioned products potato starch is considered far superior to other starches, on account of its greater swell or expansive power, and the firmness that it imparts to the product. For the other purposes corn starch is more largely used in this country, chiefly, it is believed, on account of its cheapness; and partially, no doubt, due to the fact that the manufacture of high grade potato starch has not heretofore been seriously attempted by American starch manufacturers.

2. The use of potato starch for laundry purposes may be regarded as practically nil in this country, but it has a large use in European countries.

3. The superiority of potato starch for certain manufacturing purposes is clearly recognized. The higher viscosity of properly dried potato starch makes it more desirable to use in the sizing of high grade fabrics. In lower grade fabrics its increased price over that of cornstarch makes its use more or less prohibitive. It is generally admitted that potato starch makes the best grade of dextrine now produced.

Domestic Production of Potato Starch.—The most important use that has yet been made of the potato in this country, in an industrial sense at least, is that of the manufacture of starch. The normal production of starch approximates from 20 to 25 millions of pounds. According to data published by the United States Tariff Commission in 1919, the number of establishments reporting the manufacture of starch had decreased from 131 in 1904, to 110 in 1909, and 82 in 1914. Potato starch is largely manufactured in Maine, Wisconsin, and Minnesota. Maine is said to produce over 80 per cent of the total potato starch output of the United States; and Aroostook County is the principal centre of the industry.

The price paid for cull stock ranges from 25 to 75 cents a barrel under normal conditions, with an average of about 45 to 50 cents per barrel (165 pounds).

The following data for 1904, 1909 and 1914 are from figures taken from the Census of Manufacturers; while those for 1915-1918 were compiled by the cornstarch producers, and taken from the *Textile American*, December, 1918:

Production and value of potato starch and cornstarch in the United States.

Year	Number of factories	Potato starch		Cornstarch	
		Pounds	Value	Pounds	Value
1904..	131	27,709,400	$924,476	311,140,814	$ 8,878,450
1909..	110	24,873,415	823,019	638,825,366	15,962,916
1914..	82	23,540,472	718,006	574,247,697	13,784,654
1915..				775,891,649	
1916..				868,916,578	
1917..				833,131,755	
1918..				481,761,893	

These figures indicate that a little over three million bushels of potatoes were used in the manufacture of starch in 1904, about two and three-quarter million in 1909, and somewhat less than that amount in 1914, or less than one per cent of the total crop in either of the three periods. It is evident from these data that even potato starch production furnishes but a relatively insignificant outlet for the potato crop of this country. In order to produce a stabilizing influence upon the potato industry, industrial outlets must be developed that have the possibility of using from 10 to 20 per cent of the crop.

Foreign Production of Potato Starch.—In Germany it is claimed that 4 per cent of the total potato crop is used in the manufacture of starch. While this does not seem large when thinking of it in terms of our domestic crop, it assumes a different value when considered on the basis of over a billion and a half bushel crop; it means that it would require one-sixth of our crop to offset the 4 per cent of the German crop. The following data shows the production of German potato products in 1910-11:

German production of potato products, 1910-11.

Kind of product		Quantity, pounds	Value
Potato Starch	Wet starch	125,671,700	$ 1,424,192
	Dry starch and potato meal	383,019,708	8,447,810
	Dry & wet washing starch	7,948,905	61,880
Potato sago		5,277,592	168,266
Potato meal (lump)		826,725	28,560
Glucose		21,940,400	550,018
Glucose sirup		124,332,385	3,104,472
Caramel		9,673,123	307,734
Dextrine		49,310,288	1,404,914
Soluble starch		3,602,096	107,100
Dried pulp (residue)		27,804,636	144,942
Wet and steamed pulp		513,556,940	212,295
Total		1,272,964,498	$15,962,184

From *Vierteljahrshefte Statistik des Deutschen Reichs*, III, p.114, Berlin, 1914.

Starch Imports.—Prior to the war, Germany and the Netherlands supplied practically all of the starch imported into the United States. From 1909 to 1913, the imports averaged 13,730,665 pounds, valued at $375,767; and from 1914 to 1918, they averaged 15,143,778 pounds, valued at $704,712. During the war, the imports shifted from Germany and the Netherlands to Japan and Canada. Figures for 1917 and 1918 show that Japan's exports of potato starch to this country were 18,008,666 and 21,806,975 pounds respectively, with a valuation of $799,775 and $1,494,131. The total imports from all sources during these two years were 20,647,893, and 23,852,145 pounds, or an amount in 1918 equal to our total production of potato starch in 1914. It is claimed that approximately 95 per cent of the starch imported into the United States is potato starch.

Why Import Starch?—The question might well be raised as to the economic reasons for the consumption of foreign-made potato starch in this country. There is but one logical reason—the uncertainty of a sufficiently large supply of cheap potatoes each season to make possible the profitable operation here of a starch factory. The only seasons in which, under normal conditions, it is possible to manufacture starch at a price sufficiently low to keep out foreign-made starch are when there is an over-production; when late blight rot is prevalent in those sections where starch factories are located; or when, from one cause or another, there is an unusually large percentage of unsalable stock. In seasons when the crop is short, the only stock available is that which cannot be disposed of for table purposes. European countries are able to produce potatoes at a sufficiently low cost to permit the starch manufacturers to buy table stock, at prices, that in this country would mean financial ruin to the growers.

POTATO FLOUR

The possibility of using potato flour as a partial substitute for wheat flour in bread making was forcibly brought to the attention of the American housewife when the plea was made by the U. S. Food Administration to conserve wheat flour by the use of substitutes. Unfortunately, the scarcity of potato flour and its relatively high cost as compared with wheat flour, together with unfamiliarity in its use, proved to be too great an obstacle to be overcome in such a comparatively short period of time. The interest awakened in its possibilities has not, however, subsided as will be noted under domestic production.

Potato Flour Manufacture.—In order to manufacture a high grade potato flour it is necessary to use sound stock. It does not follow, however, that it must necessarily be of No. 1 grade. In fact, it has been demonstrated within the past three years that it is perfectly feasible to make a good quality potato flour from sound No. 2 and cull stock. In seasons of over-production it offers an outlet for the surplus table stock, thereby preventing a total loss to the grower.

The manufacture of potato flour requires a greater initial outlay for both equipment and building than that involved in the production of starch. The cost of building and equipping what is termed a single unit plant requires an initial expenditure of from $20,000 to $30,000 or more, depending upon the character of the building erected, and the amount of storage space provided for the raw material and the manufactured product.

The machinery consists of a washer, long conveyor, cooker, two spiral screw conveyors, flaking machine, blower, grinding mill, and a bolter.

The first step in the manufacture of potato flour is identical with that involved in making starch, that is, the potatoes must be thoroughly washed. After passing through the washer they are carried by a belt conveyor to the steam autoclave or cooker, and if an especially fine product is desired, women or girls are stationed along the conveyor to cut or remove all unsound or sunburned material. In a medium-sized factory the steam cooker used has a load capacity of from 750 to 800 pounds of potatoes. At 240 degrees F. it requires about fifteen minutes to cook the potatoes. The cooked tubers pass from the cooked through a screw or ribbon conveyor to a hopper above the drying cylinders and from thence they pass through a set of rollers which crushes and distributes them in an even, thin layer on the surface of the steam heated cylinder, which in the course of a single revolution removes most of the excess moisture, and imparts enough heat to the potato to dissipate still further moisture. The thin layer of potato is removed from the cylinder by means of flexible knife blades. The dried flakes are removed from the flaker or drier by means of a screw conveyor which breaks up the material, and it is then elevated to a bin above the grinding mill. The flakes are then ground and bolted, and the flour sacked.

The potato flour thus secured by this process is, in reality, a cooked product. It embodies all of the chemical constituents of the potato tuber, and thus retains all of the mineral salts, which are generally regarded by dietitians as being highly necessary to the health of the body. In this connection, it is very desirable to remember that, in the past, a large percentage of the potato flour offered for sale in this country was really a potato starch flour, that is, starch re-ground and bolted. The legality of such naming has been questioned, and a ruling rendered which makes it a misdemeanor to brand potato starch as potato flour. The justice of such a ruling is apparent to all. Potato starch flour is practically pure starch. All the mineral salts and protein compounds were lost in the manufacture of the starch; furthermore, it is not a cooked product and, therefore, even though its composition was identical, it would still give different results when used for the manufacture of bread.

Domestic Production.—Had the question been asked prior to the war, one would have been obliged to answer that no genuine potato flour was being made in the country. In 1918, however, there were five potato flour factories in operation having a combined production of two and a half million pounds. The cessation of the war has in part, at least, removed the more urgent incentive to develop a stable potato flour industry. Three of the five factories operating in 1918 are controlled by a large corporation, with sufficient available capital to enable them to spend considerable sums in the education of the public, and particularly the bakers, regarding the value of potato flour in some form in our diet. The following quotation is from an editorial in the February, 1920, issue of the Potato Magazine, p. 20:

> "The manufacture of potato flour in this country (United States) is due to become an important factor in the potato industry. The Falk Company of Pittsburgh, owning flour manufacturing plants in Michigan, Maine, Colorado, Minnesota, Wisconsin and Idaho, recently contracted with the growers in the vicinity of its Colorado plant to deliver all of their No. 2 potatoes to them for the next five years. For these No. 2's and all odd sizes and shapes that will stay on an inch and a quarter mesh screen, the growers will receive 60 cents per 100 pounds, delivered at the mill................While establishing these mills in different commercial potato-producing sections, the company has not been unmindful of the necessity of creating a market for their product. It has issued a number of attractive pamphlets telling the bakers of the advantages of potato flour................This has resulted in an excellent sale for potato flour—the newest potato product to be produced in the United States."

The future of the potato flour industry depends, in large measure, upon the ability of those engaged in it to create a growing demand for the flour; and to secure a sufficient supply of No. 2 potatoes to enable them to operate their factories over a long enough period each year, thus making it possible to place their product on the market at a reasonably low price. Such price must, of necessity, be somewhere near, though probably slightly in excess of, wheat flour.

DEHYDRATED POTATOES

Through dehydration the potato may be converted into what is commercially known as dried, sliced, cubed, shredded, or riced potatoes. When intended for human food, all dehydration methods involve the partial or complete cooking of the potato. So far as the United States is concerned, it is a war industry development. In European countries and Germany in particular, the desiccation of potatoes for human use or stock feed purposes has long been practised.

Dried, Sliced Potatoes.—In the manufacture of dried, sliced potatoes, a fair sized potato is necessary in order to secure a goodly percentage of reasonably large slices when dried. The first step in the preparation of the material is the selection of sound stock; the next is the thorough washing of the same; the third step includes the paring of the tubers which is accomplished by attrition in a power-driven centrifugal machine; the fourth step consists in the hand examination of the pared tubers and the removal of all parts not cared for by the parer; the freshly pared potatoes are then sliced by a slicing machine which cuts them into slices approximately one-eighth to one-fourth of an inch thick. The sliced potatoes are caught on wooden trays with cloth or wire bottom over which they are spread in a thin layer. They are then put into a large steam chest or autoclave for a few minutes, just long enough to cook them sufficiently so that they will not turn dark when being desiccated. The trays are then placed in a drying tunnel or chamber in which the slices quickly dry. Success or failure in the manufacture of dried, sliced potatoes is dependent upon the care exercised in each successive step of the process. A properly made product should retain its color, a light amber or straw color, and when placed in water should swell to its original size and at the same time be firm and brittle rather than pasty and leathery.

Dried, Cubed and Shredded Potatoes.—In the manufacture of dried, cubed or shredded potatoes, the same processes are followed as in drying sliced potatoes, unless they are intended for stock feed, in which case they may be dried by direct heat in flue gases.

Dried, Riced Potatoes.—The production of dried, riced potatoes differs from dried, sliced potatoes only in the later stages of manufacture. Its preparation is the same up to the point of slicing; unless the tubers are large they are cooked whole; on removal from the steam chest they are emptied into a large power-operated press, where a large plunger forces the cooked product through a perforated metal plate. The finer the perforations are in the plate the more attractive will be the product made. A very large proportion of the product turned out by American manufacturers during the war was riced through perforations at least three-eighths of an inch in diameter. The riced product was collected on trays, similar to those used in making dried, sliced potatoes, and placed in drying tunnels. When partially dry they are removed, and run through a machine that breaks up the shreds into shorter lengths; after this they are again returned to the drier, and left until a certain stage of dryness has been reached that will insure long keeping. This product was largely used in vegetable soup mixtures.

Domestic Production.—It is claimed that in 1918 there were sixteen drying plants, in the United States, engaged in producing dehydrated potatoes, with a combined output of 7 million pounds. Upon the cessation of hostilities, most of the large orders for dehydrated potatoes, placed with these manufacturers, were cancelled, with the result that this branch of the potato industry bids fair to languish and die. The only possible demand that is now likely to be made for dried potato products will be for the higher grade of dried, riced potatoes, that is, those that have been passed through a very fine ricer, and have been so handled as to preserve a bright color. Such a product is easily prepared for table use, either as mashed potatoes, or for soup.

Foreign Production.—The following statistics on the German potato-drying industry, and several other potato products for the years 1908 to 1911, published in Berlin in 1911, indicates the extent of the industry in pre-war times.

German Potato-drying Industry.

Year	Total number factories	Factories using		Am't. domestic and foreign potatoes used
		peeled potatoes	unpeeled potatoes	
1908-09	170	6	164	5,898,774 bu.
1909-10	254	8	246	12,222,302 bu.
1910-11	327	4	323	15,345,485 bu.

Other German Potato Products.

Year	Products			
	Cut and sliced	Flakes and meal	All others	Total
1908-09	14,263,762 lbs.	77,072,816 lbs.	330,690 lbs.	91,667,268 lbs.
1909-10	35,163,370 lbs.	157,143,888 lbs.	793,656 lbs.	193,100,914 lbs.
1910-11	31,878,516 lbs.	204,057,776 lbs.	661,380 lbs.	236,597,672 lbs.

DEXTRINE, GLUCOSE AND ALCOHOL PRODUCTION

Dextrine.—This is a product of starch obtained by heating it, either alone or with a diluted acid. It is regarded by some as an intermediate product between starch and glucose. Dextrine is soluble in water and possesses strong adhesive properties. It is sold on the market under the names of potato dextrine, corn dextrine, tapioca dextrine, British gum and burnt starch. The last two terms are generally applied to the cruder product.

Method of Manufacture of Dextrine.—As previously noted, dextrine is a product of heated starch, or of starch treated with dilute acid. It is usually made by heating starch in an oil bath or steam jacket. When acid is used, the starch is moistened with dilute acid and then air-dried; or else it is heated at a low temperature and finally the finely ground product is placed in a suitable oven, heated with steam. Continuous stirring is necessary to insure a perfect mixture. Acid-treated starch usually makes a lighter colored dextrine, but the sugar it contains lessens its adhesive properties. A loss of some 20 to 25 per cent is involved in the conversion of starch into dextrine. This loss is, in part, compensated for through the absorption of moisture by the dextrine.

It is claimed that dextrine made from potato starch has a greater adhesive power than that from other starches, and is said to be generally preferred in the textile trades. It also makes a very satisfactory product for gumming envelopes and stamps.

Domestic Production of Dextrine.—The United States now possesses the largest plants for the manufacture of dextrine. Prior to the war little, if any, potato dextrine was manufactured, production being limited almost entirely to corn dextrine.

In point of value, potato dextrine commands the highest price and corn dextrine the lowest. In 1914, imported potato dextrine brought six to seven cents per pound; the domestic article sold for five and one-half to seven cents and British gum at three and one-eighth to three and one-quarter cents; while corn dextrine ranged from three to three and one-half cents per pound. In the latter part of 1918, domestic potato dextrine quotations showed that the price had advanced to twenty cents per pound. The tariff on dextrine, (March, 1920), was three-fourths of a cent per pound.

Glucose Production.—So far as known, potato glucose is not manufactured in the United States, corn being used instead of the potato. Potato glucose is manufactured on a rather large scale in Europe from potato starch.

Alcohol Production.—The production of alcohol from potatoes is nowhere so extensively practised as in Germany. This statement is well substantiated by the number of farm and industrial stills that were in operation in that country in 1911. Skinner says[3] that on this date there were 5,577 farm stills and 17 industrial stills, used principally for the extraction of alcohol from potatoes; against 7,626 farm stills and 710 industrial stills, used chiefly for the extraction of alcohol from grain. Kremers states[1] that there are about 6,000 agricultural potato distilleries in operation in the German Empire, 4,000 of which represent one of the chief activities of the respective farms, whereas the remaining 2,000 have a secondary place.

THE NEEDS OF THE POTATO INDUSTRY

The successful development of any great industry is wholly dependent upon the demand that may be created for its product or products. A business having but one outlet for its product has a much smaller chance of attaining to as large proportions as one that has several. Many industries have been made immensely profitable through the by-products, developed from materials that, in the early stages of the industry, had been regarded as waste products. The meat industry of this country furnishes an excellent illustration of what might be practically considered the last word in the utilization of waste products. The well-known, but nevertheless trite, remark that the large meat packing houses utilize everything but the squeal of the hog, illustrates in a most forceful manner the business thrift of these large corporations. When similar principles are applied to the utilization of agricultural food crops, a long step will have been taken toward the stabilization of production. The potato industry of America has urgent need of such a stabilizing influence; in fact, until outlets are created which will provide a market for the culls, and the surplus stock in seasons of over-production, potato growing will continue to be one of the largest gambling enterprises in which the American farmer can engage. The gambling element in this crop is due to the fact that, practically speaking at least, the potato has but one outlet, that of table stock.

Per Capita Consumption.—The normal per capita consumption of potatoes in the United States is difficult to estimate with any great degree of accuracy, on account of the fact that production varies widely from year to year, with a consequent upward and downward movement of prices, all of which tends to curtail consumption. One way of estimating the per capita consumption is to take, as a basis for computation, the average annual production of the United States for the five-year period 1915-1919, or 371,708,600 bushels and divide it by the average annual population for the same period, which we will assume to be approximately 110 millions of people; this gives us a per capita average of a little less than three and one-half bushels. But such a figure represents per capita production and not per capita consumption. To arrive at the per capita consumption, it is necessary to deduct all stock unfit for table purposes, all diseased and frozen stock, to make allowance for the natural and inevitable storage shrinkage, and last but not least, deduction must be made of the seed necessary to plant the ensuing year's crop. While it is difficult to make exact estimates of the percentages ordinarily involved, it is believed that the figures given are not far amiss if applied over a series of years:

Culls or unsalable stock..............	10 per cent.
Diseased, frozen and storage shrinkage.	10 per cent.
Seed for ensuing crop................	10 per cent.

The probability is that the first two percentage figures are too low rather than too high. The last estimate may be regarded as approximately correct. Deducting 30 per cent from the total crop of 371,708,600, leaves 260,196,020 bushels available for consumption, a trifle over two and one-third bushels per year, or a per diem allowance of six and one-tenth ounces for each man, woman and child in the United States. Contrast this with a per capita consumption of seven and one-third bushels in Germany, an amount almost three times as great as that used by our own people. Assuming that the figures presented are approximately correct, it is seen that 70 per cent of the potato crop produced in the United States is used for table purposes. In Germany, it is claimed that only 28 per cent of a normal crop is used for table food. The balance of the crop is disposed of as follows: 40 per cent is fed to live stock; 12 per cent used for seed; 10 per cent for industrial purposes; and the remaining ten per cent is regarded as waste, due to decay, shrinkage and other causes. The large balance of the German crop, over and above the actual requirements for table food purposes is available in seasons of low production years, for human food. It simply means that a lesser amount is used for industrial purposes. This prevents wide fluctuations in prices, such as occur in the United States when there is a short crop.

It has been shown in a previous portion of this chapter that somewhat less than one per cent of the crop of this country is converted into starch, and that we have the beginnings of a potato flour and possibly a potato dextrine industry. Just how far it may be possible to increase all three of these industries depends, to a considerable extent, upon the degree of protection they receive from foreign competition, and to our ability to reduce the cost of production by increasing the per acre yield. The fact should not be lost sight of that these commodities are being manufactured out of the cull potatoes, with the probability that it will be some years before the industrial uses of the potato will exceed the normal supply of unsalable potatoes.

Increased Consumption Desirable.—The only way by which the consumption of potatoes may be increased is to produce a sufficient crop each season to guarantee an ample supply for table purposes at a price commensurate with their food value. This would involve a large over-production during favorable years, for which a profitable outlet would have to be created. Alternate years of high and low production, with their consequent wide fluctuation in prices are detrimental to both grower and consumer, as well as to the industry itself. When prices are high, the consumer substitutes other vegetables or vegetable products, and thus gets out of the habit of eating potatoes each day as a regular part of his or her diet. Production must be increased through the use of better seed and improved cultural practices, thereby securing larger yields per acre at a reduced cost per bushel. Consumption must be increased through a steady supply of good, sound potatoes, at a price consistent with a fair profit to the producer. Production and consumption must go hand in hand if a stable industry is to be built up.

Distribution.—Distribution is one of the important links between the producer and the consumer. Heretofore, the processes of distribution of produce from the farm to the door of the consumer have been slow, faulty and expensive because of the numerous hands through which it ordinarily passes, each one of which exacts a toll, not always in keeping with the service rendered.

POTATOES AS FEED FOR LIVESTOCK

The possibility of making greater use of potatoes as a feed for livestock should not be overlooked. It is difficult to grasp the fact that German farmers feed nearly twice as many potatoes to their farm animals as the United States produces. Some 40 million hogs are largely grown and fattened on potatoes in Germany. If we are to have a prosperous and stable agriculture, we must see to it that there is no unnecessary waste. Potatoes, when cooked or siloed and fed with grain, make a reasonably cheap and acceptable feed for swine and other farm animals, though cooking is not necessary when fed to cattle.

Round and Gore[2] have developed a cheap and satisfactory method of converting cull or surplus potatoes into silage. They summarize the result of their studies as follows:

1. "The use of 2 to 5 per cent of corn meal, mixed with crushed potatoes, insures an acid fermentation, which converts the potatoes into silage.

2. This work may be done upon any scale. If reasonable care is used, losses should be negligible.

3. The potatoes should first be washed, and then crushed by passing them through an apple grater, which has been modified by substituting rows of blunt spikes for the grater knives.

4. The fermentation requires a tight receptacle, which may be a barrel, vat, pit or silo, but must retain the potato juice.

5. The upper surface of the crushed potato should first be covered, to a depth of several inches, with an absorbent, fibrous substance such as straw, corn-stalks or leaves; then closely fitted with a wooden cover, weighted down by stones, until the surface of the potatoes is barely covered by juice. The top of the straw and the board cover should be kept dry.

6. Fermentation begins at once. With the evolution of gas, considerable pressure develops, which should be controlled by extra weights. After a few days this pressure disappears. Acid fermentation continues, however, for two or three weeks. As in other fermentations, the length of time necessary is directly dependent on the temperature.

7. The resulting potato silage is refreshingly acid in flavor, free from any putrid odors and of about the consistency and appearance of the original crushed potato.

8. Potato silage is eaten freely by cattle, and somewhat less readily at first by hogs, although they soon learn to eat it"

In sections where there are no starch or potato-flour factories to utilize the culls or surplus stock, good agriculture demands that some provision be made to feed them to livestock, and thereby utilize their feed values, thus increasing our dairy and meat products.

QUESTIONS ON THE TEXT

1. What determines the value of a food crop for industrial purposes?
2. What does a chemical analysis of the potato reveal as to its constituents?
3. What is its most important constituent?
4. In what other crops does starch occur abundantly?
5. What are the chief manufactured products of the potato?
6. From what portion of the potato crop of the United States is starch manufactured?
7. Describe the successive steps involved in the manufacture of starch.
8. What is the average yield of commercial starch from cull potatoes?
9. What are the commercial outlets for all kinds of starches?
10. What are the chief uses made of potato starch?
11. To what extent is potato starch manufactured in the United States?
12. In what states is potato starch most largely manufactured?
13. Which state is of greatest importance and what per cent of the total output is made in this state?
14. What is the usual or normal price paid for potatoes by starch manufacturers?
15. How many starch factories were in operation in the United States in 1904, 1909 and 1914?
16. How did the output of potato starch compare with that of cornstarch during these periods?
17. About how many bushels of potatoes were required for starch purposes and what per cent of the total crop did it represent?
18. How does this amount compare with that of Germany?
19. What proportion of our crop would 4 per cent of the German crop represent?
20. How extensive are the imports of starch into the United States?
21. How did these imports shift during the war?
22. What economic factors are involved in the manufacture of a constant supply of potato starch?
23. When did the American public first become interested in potato flour?
24. Describe the processes involved in the manufacture of potato flour.
25. What is the difference between potato flour and potato starch flour?
26. Upon what does the future of the potato flour industry depend?
27. What are the ordinary products manufactured from the potato through the process of dehydration?
28. How is the industry to be regarded in the United States?
29. Describe the processes involved in the manufacture of good, dried, sliced potatoes.
30. Describe the manufacture of dried, riced potatoes.
31. To what extent were dried potato products manufactured during the war?
32. What is the present status of the industry?
33. Of what commercial importance is the potato drying industry in Germany? In the United States?
34. Describe processes involved in the manufacture of potato dextrine.
35. How does potato dextrine compare in value with that of dextrine made from other starches?
36. Of what importance is potato glucose production?
37. In what country has potato alcohol production become an important commercial industry?
38. What are the needs of the potato industry in the United States?
39. What is the average per capita production in the United States?

40. How does the average per capita consumption in the United States compare with that of Germany?
41. What percentage of the total German potato crop is consumed for table purposes?
42. How does the German percentage compare with that of the United States?
43. How is the balance of the German crop utilized?
44. How does the large excess of potatoes over and above the needs of the German people for table purposes tend to stabilize the price?
45. What effect does alternate years of high and low production have upon the table consumption of potatoes in this country?
46. What is the solution of the problem of high and low production with its consequent price fluctuations?
47. What is the relation of distribution to crop production?
48. Along what other lines may we increase potato consumption?
49. Describe the process of making silage out of the potato.

EXERCISES SUGGESTED BY THE TEXT

1. Collect a set of samples of potato products and preserve them in glass jars or bottles.
2. Examine potato tissue under a strong microscope.
3. Draw several grains of potato starch showing the layers.
4. Grate a large potato, using a kitchen vegetable grater. Hold the material in a cheesecloth and wash thoroughly in a dish of water to remove the starch. Allow it to settle, remove the water and dry the starch.
5. Weigh the starch from a given weight of potato and determine the percentage of starch.
6. Determine the percentage of water in a potato by weighing, slicing, drying and weighing again.

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PART II

CHAPTER XIX

THE BOTANY OF THE POTATO

THE potato is botanically known as *Solanum tuberosum*, L., and is a member of the *Solanaceæ* or nightshade family of plants. The tomato, eggplant and pepper are close relatives of the potato.

In discussing the genus *Solanum*, Baker[2] claims that it

"is one of the largest genera in the vegetable kingdom. About 900 names stand in the botanical books as species, and Bentham and Hooker estimate that probably 700 of these are really distinct. Of these 700 it is only six that grow potatoes at all, and the remainder all maintain their hold in the world, as most plants do, by means of their flowers, fruits and seeds." The six tuber-bearing species, according to Baker's conclusions (p. 504, 505), are: (1) *Solanum tuberosum*, L.; (2) *S. Maglia*, Schlecht; (3) *S. Commersoni*, Dunal; (4) *S. cardiophyllum*, Lindley; (5) *S. Jamesii*, Torrey; (6) *S. oxycarpum*, Schiede.

More recent studies by Bitter,[3] of Bremen, Germany, have resulted in a much larger list of tuber-bearing species than is contained in Baker's list. An enumeration of Bitter's species, as well as those of others, is not, however, considered pertinent to the present discussion. It is, however, thought desirable to give Baker's description (*l.c.* p. 489), made from the living plant, of a typical specimen grown in the herbaceous ground at Kew Gardens, England:

Description.—"Rootstock bearing copious large tubers. Stems stout, erect, flexuose, much branched, one to two feet long, slightly hairy, distinctly winged on the angles. Leaves pseudo-stipulate, a fully developed one about half a foot long, with seven to nine finely pilose, oblong, acute, large leaflets, the side ones stalked and unequally cordate at the base, the one to two lowest pairs much dwarfed, leaving a naked petiole about an inch long, the rhachis furnished with numerous small leaflets, interspersed between those of full size. Flowers numerous, arranged in compound terminal cymes, with long peduncles; pedicels hairy, articulated about the middle. Calyx hairy, one-fourth to one-third inch long, teeth deltoid-cuspidate, as long as, or a little longer than, the campanulate tube. Corolla dark lilac, subrotate, nearly an inch in diameter, pilose externally; segments deltoid, half as long as the tube. Anthers bright orange-yellow, linear-oblong, nearly one-fourth inch long; filaments very short. Berry perfectly globose, smooth, under an inch in diameter.

The potato tuber arises as a terminal enlargement or swelling of a thick, and usually rather short, underground stolon. These tuber-bearing stolons arise from what above ground would be the axils of the leaves, on the main stem of the plant, extend more or less horizontally outwards, and sooner or later normally swell up

Fig. 199.—Early stage of tuber development. Note special tuber-bearing stolons.

at their tips to form tubers (Figs. 199 and 200). In this connection, Reed[6] says:

"That these structures are stems is shown by their origin and their anatomical and morphological structure."

Arthur[1] describes the potato tuber as follows:

"The potato tuber is a thickened stem, having the cells mostly filled with starch as a reserve food for the new plants. The eyes are the promise of the future branches. The skin differs from the surface covering of the rest of the plant by being formed of a layer of delicate cork with its accompanying lenticels, and the fibrous framework, as well as the pith, is continued from the leaf-bearing stems into the tuber with relatively little change. Liquids move from part to part, most readily through the fibrous tissue, and not through the proper pith. This indicates that in

Fig. 200.—A more advanced stage of tuber development than in Fig. 199.

cutting seed potatoes, the movements of the nutrient sap in germination have no bearing upon the question of the best form of the pieces, except that they should reach deep enough to include the wood ring."

In Baker's technical description of the plant he says that the stem is distinctly winged. This statement was, of course, based on the plant he described and does not necessarily apply to all of our cultivated varieties, as many of them are not winged or if they are, it is very slight. The same explanation should be made regarding the color of the flowers, which, while constant in any given variety or group of varieties, is not constant with respect to all varieties. It is well known that the color of the flower may vary with the variety, from the delicate creamy-white through all shades of pink, rose-purple, lavender and blue. In fact, many of them are extremely attractive in color and large in size, especially in seedlings resulting from South American crosses.

Parts of a Potato Tuber.—The potato tuber may be anatomically divided into four rather distinct parts or zones which are morphologically known as: (1) The envelope or skin; (2) the cortical layer; (3) the external medullary area, and (4) the internal medullary area. The delimitations of 1 and 2 are clearly defined but that of 3 and 4 are not so clearly separable. They are usually defined as follows:

1. The envelope or skin comprises the corky or outer covering of the tuber, corresponding to the bark of an above-ground stem.

2. The cortical layer consists of the peripheral zone immediately beneath the skin. This zone or layer may vary from one-eighth to one-half an inch in thickness. It is denser and less translucent than the external medullary area, from which it is separated by a well-defined line or ring of fibro-vascular bundles. If exposed to light, this part of the tuber quickly turns green, and acquires a distinctly acrid taste due to an accumulation of a poisonous substance, chemically known as *solanin.*

3. The external medullary area embraces the outer portion of the strictly fleshy part of the tuber. It is generally interpreted as including the denser portion of the medullary area.

4. The internal medullary area includes the watery and more translucent central part of the tuber.

Langworthy[5] states that, according to determinations made in the Department's laboratories, the actual skin of the potato represents about 2.5 per cent of the whole, the cortical layer about 8.5 per cent, leaving 89 per cent for the medullary areas. This differs quite appreciably from the percentages given by Coudon and Bussard[4] as will be noted from the following figures:

Envelope or skin	8.79 per cent.
Cortical layer	36.19 per cent.
External medullary area	34.17 per cent.
Internal medullary area	14.96 per cent.

From the botanical standpoint, these variations in percentages are of no material consequence to the present discussion. It is, perhaps, permissible, however, to say that from the chemical standpoint the relative proportion of these four parts of the potato is vitally important, as it is materially concerned with its food value. The cortical layer is of especial interest, because it contains, in addition to starch, a higher percentage of mineral matter, soluble carbohydrates and nitrogenous matter, as well as of acid substances, than do the other parts of the tubers.

QUESTIONS ON THE TEXT

1. Under what name is the potato botanically known?
2. Is the *Solanum* group a large one? Name common garden crops of this group.
3. How many, according to Baker, are tuber-bearing? Name them.
4. Does Dr. Bitter concur with Baker in his limitation of tuber-bearing species?
5. What is the potato morphologically?
6. What can you say regarding the winged stems?
7. Name the four parts of a potato tuber.
8. Describe each.

EXERCISES ON THE TEXT

1. Compare the flowers of potato, tomato, eggplant or others of the family and note likenesses.
2. Read the floral descriptions in a good botany book and compare with the specimens.
3. Study the morphology of the underground parts of a potato plant and show that underground stems do exist.
4. Preserve some of these underground parts with small tubers in a glass jar. Use two per cent formalin water.
5. Find specimens showing the winged stems and others where the wings are less prominent.
6. Make sections of potato tubers and point out the four parts.
7. Draw and label parts.

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CHAPTER XX

ORIGIN AND EARLY HISTORY OF THE POTATO

Origin.—For over a century the question of the origin of the potato has occupied the minds of many botanical explorers and naturalists. While scientists are agreed that the potato is indigenous to South America, they are divided in their beliefs concerning the particular locality in which the wild tuber-bearing species, of which it is a descendant, originally occurred. One group of scientists claim Chili as the original home of the potato, while another group are inclined to regard Peru, or Peru and Bolivia, as the region from which it came. Those who regard Chili as its source appear to be in the majority; but, to the writer, the evidence seems to be in favor of Peru, or possibly of the whole Andean section of South America, stretching from the northern boundary of Ecuador to the southern portion of Peru.

Wight's[13] summation of the evidence both for and against its Chilean origin is a comprehensive review of the more important literature on the subject. His conclusions, based on the literature, a critical examination of material in American and European herbarias, and a six months' exploration trip through Chili, Peru, Bolivia and Ecuador, (made for the express purpose of securing first-hand information concerning the existence of the wild form *Solanum tuberosum*, L.), are as follows:

> "Every reported occurrence of wild *S. tuberosum* that I have been able to trace to a specimen, either living or preserved in the herbarium, has proved to be a different species. In fact, so far as the herbarium material is concerned, I have not found in any of the principal European collections, a single specimen of *Solanum tuberosum* collected in an undoubtedly wild state. After a century and a half of intermittent collecting, there is no botanical evidence that the species is now growing in its original indigenous condition anywhere. So far as the number and relationship of the species referred to the section tuberarium are concerned, the evidence is in favor of the central Andean region."

The central Andean region referred to comprises northern Chili, Peru, Bolivia and Ecuador.

Early History.—The first mention of the potato in literature is that found in Cieca's *"Chronicles of Peru"* published in Seville, Spain, in 1553. Cieca was a young Spanish adventurer who, at the early age of fourteen, sailed with an expedition from Spain to Cartagena, where he landed in January, 1833. In 1838 he joined an expeditionary force that crossed the mountains and advanced up the valley of the Cauca. In 1541 he began to keep a journal which he continued throughout his soldier's career, which took him southward as far as the mines of Potosi in southern Peru. Among the many interesting data recorded by Cieca in his journal were those pertaining to the agricultural regions, through which he and his soldier companions fought their way southward. In Markham's[7] English translation of Cieca's *Chronicles,* the potato is alluded to seven different times in connection with different localities through which he passed.

On page 117 he says: "In the Provinces of Chapanchita, Bomba and Popayan....they gather great quantities of potatoes." On page 121: "The districts of Pasto yield but little maize....The country yields much barley, potatoes, etc." Page 131: "In all these villages (Pasto, Funes, Gualmatan and Ipiales), they grow many potatoes." Page 143: "Of provision besides maize, there are two other products which form the principal food of these Indians. One is called potato." Page 174: "In the Province of Santiago de Puerto Viejo the land is fertile, yielding an abundance of maize, yucas, aji, potatoes and many other roots." Page 234, in speaking of the crops grown in the fertile coast valleys, Cieca says: "They also raise sweet potatoes....besides potatoes, beans and other vegetables." Pages 360-361, in speaking of the Callao region, he says of the inhabitants: "Their principal food is potatoes which are like earth nuts....They dry these potatoes in the sun and keep them from one harvest to the next. After they are dried they call these potatoes chuñus, and they are highly esteemed and valued among them. They have no water in channels for irrigating the fields, as in many other parts of this kingdom, so that, if the natural supply of water required for the crop fails, they would suffer from famine and want if they had not this store of dried potatoes. Many Spaniards have enriched themselves and returned prosperous to Spain, by merely taking these chunus to sell at the mines of Potosi." Cieca describes the climate of the Callao region as being "so cold that there is no maize, nor any kind of tree; and the land is too sterile to yield any of the fruits which grow in other parts."

From the above mention of the potato it is quite evident that it was a common article of food, and rather generally cultivated throughout a considerable portion of the region transversed by Cieca; or from the southern portion of what is now known as Colombia, to the region of Lake Titicaca or beyond. That Cieca and later writers recognized that the potato, or "papas" as it was universally called by the Indians, had long been under cultivation in that region is quite evident from their writings. It is not strange, therefore, that after a lapse of nearly four centuries the evidences of its origin should be so obscured as to make it impossible for any person, no matter how well versed in the origin of our cultivated plants he may be, to determine definitely what the original wild form may have been. There is no certainty that the plant, to which the name *Solanum tuberosum*, L. was given, was a pure wild species. The reason for making such a statement is due to the fact that the plants originally studied and described by both Bauhin[2] and Clusius[3] did not represent a pure wild species because, according to both of these botanists, there were both purple and white flowering plants among the seedlings grown from them. This is directly opposed to the behavior of seedlings grown from any of the wild species studied in the past fifteen years. In not a single instance has it been found that such seedlings bore either flowers or tubers that were sensibly different, either in color or in form, from that of the parental plant. These observations were made on the following species of *Solanums*: *cardiophyllum, demissum, verrucosum, utile, polyademium* and several unidentified ones from South America. While the above observation does not necessarily prove the statement made, as to the unlikelihood of the original forms studied being simon-pure with respect to certain unit characters, as, for example, color of flowers and tubers, it does afford conclusive evidence that at some time during the centuries preceding those in which the Spaniards found the potato occupying an important place as an article of food in the Andean region of South America, two or more species must have hybridized; or else we must accept the De Vriesian theory, and assume that mutants appeared in the original wild species. It is known that, at the time of the conquest of Peru, more than one variety of potato was being grown by the natives; and that then, as in many sections of South America today, the potato was very largely reproduced from true seed, rather than from the tubers. It is the exception rather than the rule today, to find the Indian in the Andean region growing but one variety in his potato plot; the chances are strongly in favor of his having a dozen or more different varieties (seedlings) intermingled with one another.

Introduction into Europe.—Its introduction into Europe is supposed to have occurred shortly after the Spanish conquest of Peru, or about the middle of the sixteenth century. That it may have been carried to Europe at a somewhat earlier date is, of course, possible, but hardly probable, since it would have attracted the notice of some of the European botanists of that period. It is thought to have been carried into Italy from Spain, and from Italy into central Europe.

In the meantime, the potato is supposed to have found its way into the Old World from another and entirely distinct source, if we are to believe the commonly accepted notion that, in 1586, it was brought to England in one of Sir Walter Raleigh's ships, on its return from the colony which Sir Walter established in Virginia in 1584. Upon this introduction, or theory of it, Wight (*l.c.* p. 39) says:

"The idea that the potato was introduced from Virginia into England, is, however, so prevalent in literature that it should have some consideration, even though the claim is not made that the potato was native to Virginia. Few, in fact, have believed that it was cultivated by the Indians previous to the era of European exploration and settlement; and no evidence has ever been brought forward, so far as I am aware, in support of such a contention. The conclusion in regard to its introduction from Virginia rests solely on the assumption that the root (called by the Indian Openauk), described by Thomas Hariot in *A brief and true report of the new found land of Virginia*, first printed in London in 1588, is the potato; and is also the plant described by Gerard in his *Herball*, issued in 1598. Hariot says: 'These roots are found in moist and marshy grounds, growing many together in ropes as though they were fastened to a string.' He states that they grew naturally or wild, which would be improbable if they were potatoes introduced after the discovery. The description also applies better to *Apios tuberosa*, the ground nut, than it does to the potato. Furthermore, the Indians would scarcely have had a distinctive name for a plant so recently introduced.

"We may assume, from the evidence at hand as to the improbability of the potato being known, and still less cultivated in Virginia at that time, that if Raleigh's vessels in charge of Sir Francis Drake did bring the potato to England on the date mentioned, they must have secured it from some South American trading vessel, or at a point other than Virginia."

The first published description of the potato found is by Bauhin.[2] While it was based on rather scanty material, it is sufficiently comprehensive and accurate as to leave no doubt in the reader's mind as to its being the potato. In describing the plant Bauhin says:

"The stem is in the form of a stalk about one and one-half to two feet in length; fruit in the shape of a golden apple, nearly round.....stem green, somewhat branched, nevertheless it sometimes reaches the height of a man.....Leaves about the length of the hand, rough on the under side with pale hair. Much divided into six, eight or more or less parts; like single leaves, to the number of which an odd one is always added; round to oblong, simple, arranged opposite and there are usually two, six or more small leaves interspersed along the leaf stalk.

"The branches are usually divided into two stalks, each of which bears many flowers, some closed and three or four open, ranging from blue to purplish, spreading out into five points which somewhat greenish-yellow lines traverse and divide; in the centre there are usually bunched four reddish stamens, as in *Malum insanum*.

"The flowers are succeeded by single round fruits, hanging on long stems, like a cluster, as in *Solanum vulgare*, but far larger; for some of them equal a nut (probably a walnut) in size; some of them indeed grow no larger than a filbert, all nevertheless striped with equal lines, like the *Malum aureum*, which range from green to blackish and, when mature,

Fig. 201.—Bauhin in *Prodromus Theatri Botanici*, 1620.

to a dark red (probably a dark purplish-black). In these the seed is small, flat and round, somewhat swarthy.

"The root is round, but not circular, of a swarthy or dark red color; it is taken up from the earth in the winter time, and is returned to the earth in the spring.

"At the base of the stem, at the head of the main root, long fibrous roots are spread out, on some of which small, round roots are borne (tubers).

"We name this *Solanum* because of a certain form of its leaves and of the fruit, which is like *Malum aureum;* then, of the flowers, which are like *Malum insanum;* then, of its seed, which corresponds to the Solani; and, finally, on account of the unpleasant odor of it, common to the Solani."

In giving his source of information Bauhin says:

"The seed was sent under the name of pappas of the Spaniards, and originally of the Indians, which grew easily in our garden almost like a leafy shrub, as in the garden of Dr. Martinius Chmielecius, who had one with a white blossom. On account of our long-standing friendship, Dr.

Laurentius Scholtzius, a physician, sent me a drawing of a plant that he had grown in his garden, sketched in colors, but without fruit, and the root appendages." * (Fig. 201).

In this publication Bauhin names the potato *Solanum tuberosum,* but in *Prodromus Theatri Botanici,* published in 1620, he changes the name to *S. tuberosum esculentum.*

According to Mitchell,[9] Gerard in his 1596 catalogue applied the name of *"Papas orbiculatus"* to the potato. He evidently

Fig. 202.—Reproduction from Gerard's Herball, 1597.

changed his mind when he published his *Herball* in 1597 because, as will be seen from the reproduction (Fig. 202), he renamed it *Batata virginiana sine Virginanorum et Papus.*—Potatoes of Vir-

* Translated from the Latin by Mrs. Grace Graham Brannin.

ginia. In his 1599 catalogue he again refers to it as *Papas orbiculatus.* Wight (*l.c.* p. 40) in commenting on these inconsistencies says:

> "It is curious, if Gerard had the plant described by Hariot, that he did not use his name (Openauk) instead of a word which is not known to have occurred in the Indian language within the present border of the United States or Canada. The question of how Gerard came by the word 'papas' may be settled with reasonable certainty, for he says: 'It groweth naturally in America where it was first discovered, as reporteth C. Clusius....It is doubtful if Clusius would have reported anything concerning the potato before he had received tubers, which was in 1588, two years after Hariot's return from America; yet Gerard says: 'since which time (referring to the statement of Clusius) he had received roots from Virginia,' and this would indicate that he must have received roots from some other voyage. The figure in the *Herball* is in two parts, and it may be doubted if the tubers figured are potatoes, at least this part of the figure, for some reason, is changed in Johnson's edition of the *Herball* in 1636."

If judged literally, one might well question whether Gerard's illustration of the root and tuber development of the potato was really made from the potato. If, on the other hand, we regard it as a purely diagrammatic drawing, we may accept it for what it is intended to convey, rather than what it actually does convey to the mind. The stem, leaves, flowers and fruits are sufficiently accurate as to leave no question in one's mind as to its identity.

In 1601, Clusius published a description of the potato in his *Rariorum Plantarum Historia,* Chap. LII, p. LXXIX, in which he calls it *Papas Peruanorum.* Clusius begins his description by saying:

> "There is an edible root of a new plant, which but a few years ago was not known in Europe.....It springs at first from a bulb, which, with us, starts into growth about April, not later; within a few days after planting it puts forth leaves of a dark purplish color, hairy, which, presently unfolding, show a green color; 5, 7 or more leaflets on the same stem, not very different from the radish, always of an odd number, some smaller leaves being interspersed, and the odd one always occupying the extreme tip of the petiole. The stem is of the thickness of the thumb, angular, and covered with down. From the axils of the petioles coarse stalks appear, angular pedicels, bearing 10 to 12 or more flowers about an inch or more across, angular, consisting of one piece, but so folded that there appear to be five separate leaves, of a whitish-purple on the outside, inside purplish, with five green rays appearing from the centre like a star, with yellow stamens gathered together in the centre, and a prominent greenish style. After the flowers, which bear an odor resembling the odor of the flowers of the linden, roundish apples appear, not much different from the fruit of the mandrake, only smaller, green at first, white at maturity; full of juicy pulp which contain many flat seeds scarcely larger than the seeds of the fig."

In describing the tuber development he says:

FIG. 203.—Reproduction of drawing of potato stem sent to Clusius by Philip de Sivey in 1588.

"When, in the month of November, the plant is dug after the first frosts, there are discovered tubers of various sizes. These are uneven, recognized by certain marks whence, the following year, shoots will start forth. I remember, also, that there were collected more than 50 tubers from one single plant, some so large that they weigh an ounce or even two, the outside skin reddish or approaching a purple color, some small, as though not yet mature; they have a whitish skin which is very tender in all the tubers, but the flesh itself is firm and white.

"From the tubers *alone* therefore, we must expect the preservation of the genus, and from the seed, the daughter plants of which, in the same year, bear blossoms, but of a different color from the mother plant. So I have learned from others, though I have never tried the experiment

Fig. 204.—Reproduction of Clusius drawings from the living potato plant, 1601.

myself. True it is that my friend Joannes Hogeladius described plants to me produced from seed which I sent him, which produced white blossoms altogether. I received the first authentic information about this plant from Phillipus de Sivey, Dn. de Walhain and Prefect of the City of Mons in Hannonia, of the Belgians, who sent two tubers of it, with its fruit, to me at Vienna, Austria, at the beginning of the year 1587, and in the following year, a drawing of a branch with a flower, (Fig. 203). He wrote that he had received it the preceding year from a certain employee of the Pontifical Legation in Belgium. Later Jacobus Garerus, Jr., sent me a Frankfort drawing of a whole stalk, with roots. Indeed, I have much desired to exhibit the whole plant here, but I have taken pains to portray it in two drawings from the living plant—one representing flowers and fruit, the other roots and tubers clinging to their own fibres, (Fig. 204).

"The Italians do not know where they were first produced. Certain it is, however, that they were obtained either from Spain or from America. It is a great wonder to me that, when it was so common and frequent in Italian settlements (so they say), that they feast upon these tubers, cooked with flesh of mutton, in the same manner as upon turnip and carrots, they give themselves the advantage of such nourishment, and allow the news of the plant to reach us in such an off-hand way. Now, indeed, in many gardens of Germany it is quite common because it is very fruitful." **

Authorities Differ.—It is apparent to the reader that there are some inconsistencies in the description of the potato by both Bauhin and Clusius. Take for example Bauhin's description of the fruits, which he says are dark red when mature. In many of the varieties from South America which have come under our observation, the mature fruits are a dark purplish-black or dark bluish-green black, whereas in all varieties that are classified under groups 1 to 12 in Chapter XII they are a light lemon-yellow color when mature.

In view of this fact, we may accept Bauhin's description of the color as not entirely inaccurate. It requires some imagination on the other hand to accept Clusius's statement that the odor of the potato flower resembles that of the linden. His description of the color of the mature fruits would indicate that the variety he had was different from that of Bauhin's. The accuracy of observation of Clusius is well indicated in his description of the color of the tubers in which he says "some small, as though not yet mature, they have a whitish skin." This observation has been repeatedly verified in studying a number of tuber-bearing species of *Solanum* from Mexico. The immature tubers very frequently do not show color, whereas when they mature, several species have always developed a purplish color.

Development of Potato Culture in Europe.—While we have little definite knowledge as to how extensively the potato was cultivated prior to the seventeenth century, we can safely assume that it had not yet emerged from the curiosity or novelty stage in its development as a staple food plant, although Clusius (*l.c.* p. 1601) says that it is reported to be more or less commonly grown in Italy, and further remarks that, because of its fruitfulness, it is quite commonly grown in many gardens of Germany. Despite these statements of Clusius, the fact remains that the potato was

** Translated from the Latin by Mrs. Grace Graham Brannin.

little grown in Europe before the latter part of the seventeenth century, and, in fact, did not become of great commercial importance until the latter half of the eighteenth century.

Development in Great Britain.—Phillips[10] says:

> "The potato first became an object of national importance in 1662-3 as appears by the record of a meeting of the Royal Society held March 18 in that year; when a letter was read....recommending the planting of potatoes in all parts of the kingdom to prevent famine.....Notwithstanding, it was not till within the last twenty years (1802) that they were used as a substitute for corn bread (wheat bread) in England, when the apprehension of a scarcity induced all prudent families to adopt the use of potatoes at their dinner tables, in lieu of bread or puddings."

Miller[8] in 1731 mentions two varieties or sorts, the red and the white which, he says, were both indifferently cultivated in England at that time. Krichauff[5] says that up to 1784 potatoes were chiefly grown in the gardens of peers and rich men; and that in 1796 Essex County, England, grew about 1,700 acres for the London market. In Scotland, he says, that prior to 1760 they were mostly grown in gardens; after that date they were more generally grown. Loudon[6] makes a very similar statement in 1830, in which he says that the cultivation of potatoes, even in gardens, was little understood prior to 1740; and that it was about twenty years later before they were much grown as a field crop. He further mentions the fact that the famous nursery firm of London and Wise did not consider the potato worthy of notice in their *Complete Gardener*, published in 1719. He also observes that, in addition to the acreage grown in Essex County in 1796, many fields could be noted in other counties bordering on the capital, (London); that many shiploads were annually imported from a distance; and that in 1830, the potato was more or less an object of field culture in every county in England.

The development of potato culture in Ireland was contemporaneous with that of England; in fact, the potato, on account of its yield per acre and relative cheapness, became a vital source of food supply to the inhabitants of Ireland at a much earlier date than in England. Indeed, if we may judge acreage as a criterion of the importance of a crop, Ireland's preference for the potato is well indicated, as in 1917 she grew 709,000 acres of potatoes as against England's 473,000 and Scotland's 148,000.

Potato Development in Prussia.—The following incident, recorded by Krichauff (*l.c.*), casts a rather interesting sidelight on the attitude of the Prussian peasants and the people in general toward the use of the potato as a food plant. The incident cited is as follows:

"Frederick the Great of Prussia was more successful than his father in introducing the cultivation of potatoes into Pomerania and elsewhere; but he had recourse to his soldiery, who had to force the farmers to plant them. If it had not been for the great famine in Germany in 1771-72, the great benefit of the cultivation of potatoes would not have been so generally acknowledged."

Potato Development in France.—Potato development in France was somewhat slower than in Great Britain, Germany, Austria or the adjoining countries. Krichauff (*l.c.*) says:

"In 1771 a high prize was offered by the Academy of Besancon for the discovery of a new food which would fill the place of cereals in case of a famine. Parmentier showed his potatoes, and Louis XVI gave him 50 morgen of land (a morgen equals 2.11 acres) to plant them on. When showing the first flowers of his potatoes the king used them as a buttonhole bouquet; Queen Marie Antoinette had them in the evening in her hair, and at once princes, dukes and high functionaries went to Parmentier to obtain such flowers. All Paris talked of nothing but potatoes and the cultivator of them. The king said: 'France will thank you some time hence, because you have found bread for the poor.' And France has not forgotten Parmentier, for I saw for myself in 1882, potatoes growing on his grave in the grand cemetery of Paris, the Père Lachaise, and I was assured that they were planted there every year so that his services might never be forgotten by Frenchmen"

Vilmorin[11] admits that the culture of the potato was well established in Germany when it was still in an embryonic stage in France, except in the Ardennes region. He further says:

"During the whole of the seventeenth century, and in all probability the greater part of the eighteenth, the potato of Clusius seems to have been solely cultivated, and did not give but a single variety with white flowers. But in 1777 Engel catalogued 40 varieties. Parmentier in 1786 counted 11 and in 1809, 12, saying, elsewhere, that other authors cited more than 60 varieties. The Society National d'Agriculture de France (then Imperial) gathered together in 1814 and 1815 a collection of 115 to 120 varieties, which was confided to my great-great-grandfather and which was the beginning of a collection that I still possess."

Potato Development in Sweden.—In an unsigned article appearing in the page devoted to "short notes from papers" of *The Gentleman's Mag.* vol. 34, p. 579, 1764, the following mention is made of potato culture in Sweden:

"It seems strange to us, but it seems it is a fact, that the Swedes have but just discovered the culture of potatoes, notwithstanding the indefatigable industry of the great Linnæus. A royal edict, however, is now issued to encourage their cultivation."

Potato Development in India.—The following remarks by Johnson[4] are illuminating in that they reveal very much the same conditions as in Europe:

"At the horticultural show in Calcutta during 1842, I saw potatoes exhibited which would not have shamed the potato growers of Lancashire, (England), if mistaken for their produce. These were grown in the immediate vicinity of the city, but in the hills of Chirra Pongie, though not far distant, the potatoes are grown still finer. They were an object of cultivation there during the Governor-Generalship of Warren Hastings (1772-1785), and alluding to that period a writer says: "Three score years ago, a basket of potatoes, weighing about a dozen pounds, was occasionally sent, as opportunity offered, by Warren Hastings to the Governor of Bombay, and was considered an acceptable present. On reception, the members of the council were invited to dine with the Governor to partake of the rare vegetable.'"

Potato Development in America.—If we turn to America, we find that the potato was probably unknown to American agriculture in either the sixteenth or seventeenth century and that it was not until the early part of the eighteenth century that they were first introduced into this country. Watson,[12] in his *Annals of Philadelphia,* published the following paragraph regarding potatoes:

"This excellent vegetable was very slow of reception among us. It was first introduced from Ireland in 1719, by a colony of Presbyterian Irish, settled at Londonderry, in New Hampshire. They were so slow in its use in New England that, as late as 1740, it was still a practice with masters to stipulate with some apprentices that they should not be obliged to use them. The prejudice was pretty general against them that they would shorten mens' lives and make them unhealthy, and it was only when some people of the better sort chose to eat them as a palatable dish that the mass of the people were supposed to give them countenance."

On page 486 of the same volume Watson further says:

"As late as my mother's childhood potatoes were then in much less esteem than now. The earliest potatoes, like the originals now discovered from South America, were very small, compared with the improved stock. They were small, bright-yellow ones, called kidney potatoes, and probably about seventy-five years ago, they then first introduced a larger kind, more like the present in use, which were called in New England the Bilboa. In Pennsylvania the same kinds of potatoes were called Spanish potatoes."

Bailey[20] makes the following statement:

"Probably the potato was served as an exotic rarity at a Harvard installation in 1707, but the tuber was not brought into cultivation in New England till the arrival of the Presbyterian immigrants from Ireland in 1718." He further states that "only two varieties were listed in 1771, yet by the end of the eighteenth century they were numerous."

QUESTIONS ON THE TEXT

1. What is the common belief regarding the origin of our cultivated potato?
2. When and where was the potato first mentioned in literature?
3. Where was the potato usually grown in those days?
4. What can you say of it as a food plant at that time?
5. How was it preserved for future use by the natives?
6. How does the evidence at hand justify an acceptance of the common belief that the present cultivated varieties of the potato are the direct descendants of the wild species *Solanum tuberosum*, L.?
7. When was the potato first introduced into Europe?
8. What does Wight say about its introduction from Virginia into England?
9. In what publication was the potato first described? What did Bauhin name it?
10. What are the inconsistencies noted in Gerard's description of the potato in his *Herball* in 1597?
11. When and where did Clusius publish his description of the potato? What did he name it?
12. What does he say about the tubers?
13. Did the potato at once become popular in Europe? If not, give reasons.
14. Give brief account of its development in Great Britain.
15. Why did the potato become popular in Ireland before it did in England or on the Continent?
16. How was the potato popularized in Prussia?
17. How did potato development in France compare with that in Great Britain and other European countries?
18. What does Krichauff say about Parmentier's part in popularizing the potato in France?
19. What does Vilmorin say about the lack of popularity of the potato in his country?
20. Compare the early culture of the potato in Sweden with that in other European countries.
21. What about potato development in India?
22. When was the potato first introduced into America, and where first grown?

EXERCISES AND QUESTIONS SUGGESTED BY THE TEXT

1. Collect flowers of several varieties of potatoes in different stages. What variation in color do you find?
2. Compare young tubers with mature ones of the same variety. What variation in color do you find?
3. In harvesting potatoes, note the attachment of potatoes to their stems. What likeness do you find, if any, to their being "attached in chains"?

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CHAPTER XXI

POTATO BREEDING AND SELECTION

To the uninitiated, the subject of plant breeding seems to be surrounded with much mystery. This is probably largely due to the fact that the reproductive organs of plants and the functions performed by them are relatively little understood by the average person, but when once familiar with these processes, plant breeding is no more mysterious than animal breeding, in fact the same general laws of reproduction apply to both.

Breeding and Selection Defined.—Before proceeding further with the discussion of breeding and selection, as related to the potato, it seems desirable to briefly define the use and the application of these two terms in the present work. Breeding, as here employed, refers strictly to sexual reproduction. Selection refers to the isolation of any desirable variation in a variety from that of the normal, and its perpetuation by asexual propagation.

Limitations of Breeding and Selection.—Broadly speaking, the limitations of potato breeding are those found within the confines of the tuber-bearing species of Solanums, but for the most part it may be regarded as being confined to the varieties occurring within the species to which the potato is assumed to belong. The breeder has, therefore, within his power the possibility of crossing two varieties, each of which may have certain desirable qualities not possessed by the other, with the view of combining them in some of the resulting offspring.

The improvement of the potato by selection is limited to the natural variations occurring within the individual variety itself. As not all such variations are heritable, one cannot always be certain that the mere selection of a variant means progress until it is thoroughly tested. The selectionist, therefore, has a much narrower field than that of the breeder.

Nineteenth Century Potato-breeding Achievements.—Little, if any, real progress was made in potato breeding prior to 1850, either in America or in Europe. From this period on, however, rapid strides were made in the development and improvement of commercial varieties of potatoes. During this period, the chief consideration in the minds of American potato breeders, aside from those of Goodrich, seemed to be that of attractive appearance, table quality and productiveness. European breeders, on the other hand, paid quite as much attention to disease resistance and starch content as to the other factors mentioned.

American Potato Breeders and Their Accomplishments.—To attempt an enumeration of all American potato breeders who have had a part in the improvement of the potato during the last half of the nineteenth century is neither feasible nor desirable. But, in order to intelligently trace the progress made, from the time of Goodrich to that of Carman and others, the following list of names is presented as worthy of mention: Goodrich, Bresee, Brownell, Pringle, Rand, Gleason, Heffron, Burbank, Alexander, Reese, Coy, Carman, Craine, Bovee, Safford and Van Ornam.

The Work of Goodrich.—The severe epidemic of late blight that swept over this country and Europe during the years 1843 to 1847, and reached its climax in Europe in 1845, causing a widespread famine in Ireland, led the Rev. Chauncey Goodrich of Utica, New York, to conceive the idea that the potato, as a result of long continued asexual propagation, had become so weakened in vigor as to be no longer able to successfully resist the attack of disease. He believed that it could only be rejuvenated through sexual reproduction, and began to make his plans for the growing of seedling potatoes, with the idea of developing more vigorous and productive varieties that would be able to very largely resist disease. Through the kindness of the American consul at Panama, Goodrich, in 1851,[12] received a small quantity of South American potatoes for breeding purposes. Among this lot was a variety which, from its rough, purple skin and its supposed place of origin, he descriptively named the Rough Purple Chili. From naturally fertilized seed balls of this variety, produced in 1852, he grew some seedlings in 1853; and from this lot one was selected as worthy of propagation. This seedling was introduced in 1857, under the name of Garnet Chili. In speaking of his work Goodrich says:

> "From the beginning of 1849 to the close of 1854 I originated about 5,400 varieties....I have but 33 sorts left, many of which I shall doubtless reject in a year or two. The 3,000 new sorts, originated in 1855 and 1856, promise better, but even among them the proportion of truly valuable ones will in the end doubtless be small."

Goodrich's statements regarding the relatively few desirable seedlings that are likely to be obtained by the plant breeder indicates a careful and conscientious rejection of all inferior plants, and a firm resolve not to offer to the trade any unmeritorious varieties. That he had a clear notion of the problem before him is evidenced by his summation of what he considered were the important traits which should be included in a valuable variety of potatoes. These are as follows: (1) Good shape; (2) white flesh; (3) hardiness; (4) freedom of growth; (5) resistance of dry weather; (6) fine flavor; (7) early maturity. Not only does he mention these attributes of a good variety but he also indulges in a discussion of varieties having the right shape and those that did not. He further shows his familiarity with the behavior of varieties, by citing those possessing what he terms good bases from which to grow a large proportion of seedlings having shapely tubers. For example, he mentions the Rough Purple Chili as a bad base to use for shape, but a good one for color of flesh and hardiness.

So far as known, Goodrich did not do any artificial crossing; all of his seedlings being produced from naturally fertilized seed balls. While in this respect he failed to perform the highest type of plant breeding, his work, nevertheless, impresses one as having been carefully conducted. The varieties that he originated were the Calico, Cuzco, Early Goodrich, Garnet Chili and several others. Of these, the Garnet Chili is still being grown as a commercial variety in some localities.

The importance of Goodrich's work lies not so much in what he himself originated, but rather in the varieties produced by others from his Garnet Chili seedling. In a remarkable tribute to Goodrich, Henry Ward Beecher says[3]:

> "There are few instances on record of zeal so interested, chiefly in two respects. First, in that he would not permit himself to be imposed upon in the judgment which he placed upon the merits of his seedlings; and, secondly, in that he worked out his benevolent labors to the end of his life, without turning his industry to his own profit. He was so busy with his experiments that he had no time to make money."

He was a prolific writer, and something like 130 articles from his pen were published in the horticultural and agricultural journals and reports of that period. There can be no question as to the tremendous impetus his work and his writings imparted to those who later followed in his footsteps.

Work of Albert Bresee.—The next important contribution to the list of potato varieties in America was the Early Rose. This variety was originated in 1861 by Albert Bresee, of Hubbardson, Vermont, from a naturally fertilized seed ball of Garnet Chili, and was introduced in a limited way in 1867. The Early Rose may be regarded as the first really promising commercial variety produced in America. It may also be regarded as the foundation stock, from which emanated many of our present day varieties. Bresee also originated King-of-the-Earlies, Peerless and Prolific.

The work of C. G. Pringle of Charlotte, Vermont, will always stand forth in the minds of American potato breeders as representing the first careful effort to cross potato varieties, with the object of combining in the resultant offspring certain desirable characters of the parent plants. Pringle was a close observer of nature, a keen student and a good botanist, and he early acquired such skill in the technic of crossing, that we find him in the early seventies contracting with a leading seedsman of New York City to produce hybridized potato seed at $1,000 per pound. Considerable seed was produced at this price and, through the seedsman, was widely disseminated. There is every reason to believe that Pringle's hybridized seed produced many varieties for which the hybridizer never received the credit. His varietal contributions were the Alpha, Adirondack, Rubicund, Ruby and Snowflake. The latter variety is still remembered for its high table quality, but on account of a weak habit of growth and comparative unproductiveness, it has practically gone out of cultivation, at least in a commercial way. The other varieties mentioned were relatively short-lived. Unfortunately for plant breeding, Pringle abandoned this field of endeavor just when his productive powers were at their zenith. He became a botanical collector and explorer, in which pursuit he was so successful as to earn the title of "Prince of collectors."

In 1876 Robert Fenn, one of England's famous potato breeders published under the caption of "*Looking Back*"[9] some very interesting correspondence between himself and Pringle relative to potato breeding. The following quotation from Pringle's letter under date of January 5, 1876, indicates how thoroughly imbued he was with the subject of potato breeding:

"Twenty years ago there was little disparity, as I suppose, between English and American potatoes. The majority of the varieties which we now employ, or certainly those which are grown most extensively, have originated since that time, and have descended from semi-domesticated varieties from South America. Hybridization of species has been one of my aims Besides the original species from the Andes, *Solanum tuberosum,* I cultivated one, very distinct, from our western territory of New Mexico, *S. Fendleri.* As yet, all my pains taken to impregnate it with pollen of the cultivated species has proved unavailing, though partially developed fruits have followed my operations, only to fall away, however, before maturity. When I learn the conditions which the plant requires, and more fully meet them, I shall succeed, doubtless. Peru can furnish still another species, *S. Montanum (vide Bot. Mag.)* and I am very anxious to secure it."

This glimpse of Pringle's work serves to show the thoroughness with which he attacked the potato-breeding problems of his day; and one can hardly refrain from indulging in retrospect as to what he might have accomplished had he continued his breeding work.

The work of C. W. Brownell of Essex, Vermont, though not of as high an order as that of Pringle, extended over a somewhat longer period and his introductions are more numerous. The best known varieties are Beauty, Best, Centennial, Early Telephone, Eureka, Superior, Winner and Vermont Beauty (Beauty of Vermont). So far as known, Brownell did not make any artificial crosses.

Albert Rand of Shelburne, and later of Bristol, Vermont, came more nearly following the same line of breeding as that of Pringle. His productions were Champion, Delaware, Matchless, Improved Peachblow and Silver Skin.

O. H. Alexander of Charlotte, Vermont, was a seedsman as well as a plant breeder, and it is a little difficult to determine whether some of his introductions were of his own origination or not. So far as known, he did not cross-pollinate potato blossoms. The seedlings that he originated were either grown from naturally fertilized seed balls or from hybridized seed produced by others. His introductions were rather numerous and one of them, at least, is extensively grown. The list is as follows: Charles Downing, Dakota Red, Everitt, Garfield, Green Mountain, Reliance, Trophy, White Mountain. Of this list, the Green Mountain is by far the most important, as it and its prototypes are among the most widely grown varieties in the northeastern United States.

The productions of Gleason and Heffron were neither numerous nor important. The former originated the Willard, and the latter the Chicago Market and Climax. Heffron was closely associated with Goodrich toward the close of the latter's life and assisted in introducing some of his seedlings.

Luther Burbank's claim to notice, in connection with potato-breeding work of this period, lies in the fact that he was fortunate enough to produce a seedling, named after himself, which became widely known and is still extensively grown in some sections, particularly in California. The story of the origin of the Burbank Seedling is not indicative of any particular effort on Burbank's part. It is simply a story of the discovery of a naturally fertilized seed ball on an Early Rose plant in his mother's garden at Lancaster, Massachusetts, in 1873; its subsequent loss and re-discovery on the ground beneath the plant; the growing of 23 seedling plants from this berry; and the selection of the most promising one which, three years later, 1876, was introduced by Gregory of Marblehead, Massachusetts, under the name of Burbank's Seedling. Contrast this record with that of Goodrich, who grew about 12,000 seedlings extending over a period of about 15 years, and out of all this number failed to produce any that brought him as much lasting fame as did Burbank's Seedling.

This simply serves to illustrate a point too frequently lost sight of by the plant breeder, and that is, that those who follow the pioneer usually reap the richest reward. Bresee produced an Early Rose from Goodrich's Garnet Chili, and Burbank produced his seedling from the Early Rose. In like manner, Alfred Reese, in 1871, obtained the Early Ohio from a naturally fertilized seed ball of the Early Rose, a variety that is still extensively grown in the Red River Valley in Minnesota and North Dakota, in the Kaw Valley in Kansas, and many other localities in the central and western states.

Coy's Productions.—E. L. Coy of Hebron, New York, obtained the Early Beauty of Hebron in the early seventies from a naturally fertilized seed ball of the Garnet Chili. This variety was introduced in 1878, and for a considerable period was rather extensively grown. It was a heavy producer of fair quality potatoes, but both vine and tuber were extremely susceptible to late blight. At the present time it is little cultivated. Coy was also the originator of the following varieties: Late Beauty of Hebron, Early Puritan, Empire State, Late Rose, Noroton Beauty, Thorburn, Vaughan and White Elephant.

Thus, within a comparatively few years, there was developed from the Garnet Chili, and its daughter the Early Rose, several varieties that are still extensively grown, and from which many others have sprung to enrich our agriculture.

The work of E. S. Carman, former editor of *The Rural New Yorker,* is of extreme interest to the plant breeder in that he introduced an entirely different strain of seedling potatoes into our agriculture. So far as we are able to judge, Carman's varieties do not possess the same blood as do those which have sprung from the Garnet Chili or the Jersey Peachblow. Unfortunately, Carman did not keep careful records of his work, and the exact parentage of his seedlings is not known. He admits that he failed to make any crosses between the varieties in his collection, and, according to his own account, even failed in the earlier years of his work to find any naturally fertilized seed balls. This lack of success in securing seeds led him to advertise widely in *The Rural New Yorker* for potato seed balls. In response to this appeal, some seed was received from Europe, and from these he produced seedlings that, in turn, bore seed balls; and from this seed he obtained his Carman Nos. 1, 2 and 3. On its introduction, Carman No. 2 was given the name of Rural New Yorker No. 2. Sir Walter Raleigh was produced from seed of the Rural New Yorker No. 2. Carman's productions have added millions of dollars to the productive wealth of the States of New York, Michigan, Wisconsin, Iowa and Minnesota, and as yet there seems to be no diminution in their vigor.

Breeders From a Few States.—Thus far all of the potato breeders discussed have been residents of some half-dozen states, all of which, except Ohio and New York belong to the New England group. The chief centres were New York and Vermont. It would hardly be fair, however, to claim that nothing had been attempted in the Middle West in the development of new varieties. Among those who have been most prominently identified with this work might be mentioned the names of Martin Bovee of Michigan, Thomas Craine of Wisconsin, and F. B. Van Ornam of Iowa. Bovee originated Bovee, Early Michigan and Pingree. Craine gave us June Eating, Keeper and Potentate. Van Ornam's contributions were Extra Early (Burpee's) and Great Divide.

In concluding this enumeration of nineteenth century potato breeders, we do not claim to have mentioned all who are entitled to recognition, nor that the list of varieties given represents all that each of them originated. The object in mind has been rather to give a running history of potato breeding from the middle of the century to its close, in order to show what influence each of the men mentioned may have exerted on the potato industry of the country as a whole, and to bring together in a concrete way such data as would seem to be most important to those interested in potato breeding.

Potato Breeding in Europe.—It is interesting to note that potato-breeding activities in Europe were coincident with those in America. That this should have been the case is not unnatural, because the same severe losses from late blight had been sustained by the European growers, and therefore the same necessity existed for the improvement of the potato through the development of more vigorous growing varieties.

Work of Paterson.—In Great Britain the name of William Paterson of Dundee, Scotland, stands out prominently as a pioneer in potato breeding work. According to Wright and Castle,[20] he was probably the first person to cross-pollinate the potato.

His first experiments were made in 1826, but it was not until 1856 that he produced anything of merit. Paterson's Victoria (1856) is regarded by many as the beginning of distinct progress in potato breeding in Great Britain. In addition to the Victoria, Paterson originated many others, but his fame as a breeder will always rest on that variety.

Fenn's Productions.—In many respects the work of Robert Fenn, in England, is very similar to that of Pringle, in America. They were both intensely interested in potato breeding and for a time kept up an active correspondence. Some reference has already been made to this correspondence, and certain extracts given of one of Pringle's letters. Similar extracts are now presented from one of Fenn's letter to Pringle under date of January 27, 1876, the citation being taken from Fenn's article *"Looking Back,"* previously given. In this letter he says:

"I seem already to have entered into your ideas concerning the mingling of blood of English and American kinds. For three years consecutively, though as yet ineffectually, I have tried to cross my Rector of Woodstock seedling with your Snowflake, as being the very best of the American varieties sent over to us. Snowflake refuses to produce me a globule of pollen or to become impregnated....This also has been the case with other American varieties, till this season a stool of that shy bloomer, Willard's Seedling, threw a stalk of flowers and, to my great satisfaction, gave me some pollen upon my thumb nail. I immediately applied the dust to the pistils of three prepared florets of my seedling Bountiful, and, in a few days, I had the inexpressible satisfaction to find impregnation complete, and the berries steadily growing. Again, some three years ago, after applying the pollen of Bountiful to some hundreds of pistils on the blossoms of the American Late Rose, I was in despair until two farewell bunches of flowers appeared in the row, when, as a last resort, I again applied the pollen of Bountiful and perseverance gave me five impregnated berries."

Fenn's first crosses were made in 1857 between Old Red Regent and American Black Kidney, also between American Black Kidney and English Red Regent. He used American varieties freely in his crosses.

James Clark should also have a place among potato breeders of his time on account of his Magnum Bonum, which, according to Dean,[6] was the result of a cross between Early Rose and Paterson's Victoria made in the early seventies. It was introduced by Sutton in 1876. For a number of years, the Magnum Bonum was very popular in Great Britain and elsewhere on account of the fact that it was a strong grower, comparatively free from disease, productive and of fairly good quality. The blood of the Magnum Bonum represented the best of American and British varieties.

Findlay's Up-to-Date, introduced toward the close of the nineteenth century, established such a reputation for this famous potato breeder as to make his subsequent productions very much sought after. These will be noted under twentieth century development. The Up-to-Date very largely supplanted Clark's Magnum Bonum.

Other British Breeders.—The good work done by Carter, Chapman, Daniels, Fidler, Forbes, Harris, Kerr, Sharpe, Sutton and Webb attests to the deep interest taken in the improvement of the potato by the potato breeders of Great Britain.

The Vilmorins in France have always been active in the conduct of plant breeding work. As a rule, however, there does not seem to have been as much interest taken in the potato by the French plant breeders as in Great Britain and Germany.

The work of Wilhelm Richter, in Germany, affords a striking example of what may be accomplished by concentration of effort upon a certain specific thing. In 1869 Richter became greatly interested in the improvement of the potato.[16] At that time, the starch content of the potato in Saxony ran from 9 to 11.5 per cent. Potatoes of English origin dominated the German market. In 1875, at the exhibition of Allenburg, Richter was able to show a number of promising seedlings, such as Richter's Imperator, Precious Stone and others. His Imperator proved to be a particularly valuable variety, and Improved Imperator is still a leading German variety. Paulsen and Cimbal have also contributed much to the development and improvement of the potato in Germany.

Twentieth Century Progress in Potato Breeding.—In many respects, the actual progress made in potato breeding in this country since 1900 falls far short of that made from 1851 to 1890. Convincing evidence of the truth of this assertion may be obtained by a careful perusal of the seed catalogues from 1867 to 1890. No such activity can be shown in any later period, nor can anything like as good descriptions of the newer introductions be found in our present day catalogues. This apparent decadence of interest in potato breeding may be partially explained by the fact that, during the nineties, the extremely low prices of farm products had a depressing effect on the potato industry.

Another factor which may have served to lessen interest in potato breeding was that, with the introduction of the Green Mountain and Rural types of potatoes, so admirably adapted as a late crop in the northeastern United States, there was little incentive to indulge in this line of effort.

In Europe, on the other hand, during the first few years of the century, the world never witnessed, and probably will never again witness, such wild excitement as prevailed during the introduction of Sutton's Discovery, and Findlay's Northern Star and Eldorado. The high prices paid for these varieties were largely due to the fact that they were heralded far and wide as being almost immune to late blight.

A similar mania prevailed in America during the years 1867 to 1869. A sale is recorded[17] in the Spring of 1868 of 150 bushels of the Early Rose for $1,000 or an average price of $66.66 per bushel. The May issue of the *American Agriculturist* 1868, p. 153, contains the announcement that a portion of the 150 bushels had been re-sold at $80 per bushel.

Beecher,[3] in his essay on "The Potato Mania," states that as high as $50 per tuber was paid for Bresee's King-of-the-Earlies.

Although a number of new varieties have been introduced by American seedsmen since 1900, it can hardly be claimed that much progress has been made along this line. The two acquisitions that offer much promise are the russet type of the Burbank and Rural group. Nothing definite is known about the origin of the Russet Burbank. So far as it is possible to determine, the Russet Rural appears to have originated in Michigan. This type of Rural has recently been accepted by growers in some sections of Michigan as their standard commercial variety.

Lack of familiarity with the newer introductions abroad, other than those mentioned, does not permit of making comparisons between them and those which were being grown commercially prior to 1900. There can hardly be said to be any lack of interest among potato breeders, as will be indicated by some of the names here presented, all of whom have been more or less actively engaged in an attempt to improve the potato. This list is as follows: Berthault, Dean, Findlay, Freckmann, Seelhorst, Heckel, Paton, Salaman, Sutton, Taylor and Wilson. It is needless to say that this list by no means represents those who are actively engaged in potato-breeding work.

Difficulties Involved in Potato Breeding.—One of the chief difficulties confronting the potato breeder is due to the fact that so many of our most desirable commercial varieties bloom very sparingly, if at all, in some localities, and that, as a rule, the most of them do not produce viable pollen in sufficient amount to impregnate the ovaries of the flowers to which it is applied. This statement applies almost equally well to the free blooming as to the shy blooming varieties.

Another difficulty encountered by the breeder is that untoward seasonal conditions at the time the blossom buds are forming may wholly prevent the full development of the flower, and, consequently, the opportunity to make crosses is lost.

A further drawback to progressive work in potato breeding is due to what might be termed the irony of fate, in that the few varieties which do produce ample viable pollen are more or less unsatisfactory from a commercial standpoint, with the result that the seedlings derived from the use of such pollen inherit many of the undesirable characteristics of their male parent.

Flowering Habits.—In discussing the flowering habits of our commercial varieties East[7] makes the following statement:

> "If we regard blossoming as invariable at some period of their life under the proper conditions, we can then divide potato varieties into several classes.
>
> 1. Varieties whose buds drop off without opening.
> 2. Varieties in which a few flowers open, but fall immediately.
> 3. Varieties whose flowers persist several days, but rarely produce viable pollen."

He estimates that about 60 per cent of our named varieties belong to the first class, and, of the varieties that do bloom, only 60 per cent have their blossoms persistent for more than one day.

East further found that unselected two-year-old seedlings gave nearly the same percentage of plants that dropped their buds before opening, the figures being 56 and 44, respectively. From these data he made the following deductions:

> "This approximately equal percentage of the different classes, both in seedlings and in named varieties, indicates that their sexual differences are inherited as distinct characters, and are not due to increased tuber formation."

Observations of the writer do not substantiate those of East relative to the percentage of non-flowering varieties, nor do they necessarily refute them, if we regard his data as merely applying to the particular locality in which his studies were made. The percentage of varieties belonging to any given class varies with the region, and is very largely dependent upon the climatic conditions under which the plants are grown. In a previous publication[17] the writer made the following statement:

> "Most varieties will produce some blossoms when grown under optimum conditions for the normal development of the plant, particularly if these conditions prevail during the stage at which flower buds are formed. In any considerable varietal collection it is inevitable that many varieties should find the conditions unsuitable for their maximum development."

As a result of over a quarter of a century's intimacy with a large varietal collection, the writer has come to recognize the fact that varieties belonging to certain groups or classes of potatoes bloom freely or sparsely according to the particular group to which they belong. For example, the members of the Irish Cobbler, Early Michigan, Early Rose, Beauty of Hebron, Green Mountain, Rural, Peachblow and Up-to-Date groups bloom profusely to very profusely in northern Maine; those of the Early Ohio and Burbank groups are only moderate bloomers, while those of the Triumph and Pearl groups are very sparse bloomers.

Abundance and Viability of the Pollen.—Great variations are found in varieties with respect to the quantity and viability of the pollen produced by them. During the years 1903 to 1907 the writer had an opportunity to observe the behavior of a wild Mexican species, *Solanum polyadenium,* with respect to the formation of seed balls. It was noted that while it bloomed rather freely throughout the growing season it seldom developed seed balls until the latter part of the summer. Examination of the stamens showed that it was not due to lack of pollen, and that its failure to develop seed balls was apparently due to a lack of viable pollen. In plant breeding studies extending over a period of sixteen years it has been the writer's privilege to examine the stamens of a great many varieties, and in but few instances has an abundance of viable pollen been found. The data show a very much larger proportion of foreign varieties producing viable pollen than of American varieties. Of the many varieties studied in the twelve groups mentioned, only four were noted which could be regarded as dependable sources from which to obtain viable pollen. These four American varieties were Early Silver Skin, Keeper, McCormick and Round Pinkeye, all of them undesirable from the standpoint of their table quality, smoothness of surface, color of skin or productiveness. There are times, however, when it is possible to secure sufficient viable pollen to make artificial crosses from varieties belonging to the Burbank, Green Mountain and Rural groups; and less infrequently from the Irish Cobbler, Triumph, Early Michigan, Early Rose, Early Ohio, Beauty of Hebron and Pearl groups. The Peachblow group is omitted because the McCormick and Round Pinkeye are members of that group. The varieties, Early Silver Skin and Keeper, do not fit into any of the groups mentioned.

More recently certain varieties of foreign origin, such as Busola and Petronius, have been found to produce an abundance of viable pollen and they seem to transmit desirable qualities to their offspring.

In a rather recent publication Salaman[15] announces that male sterility is a dominant Mendelian character.

THE TECHNIC OF POTATO BREEDING

The first consideration in the technic of plant breeding is that of the character of the flowers borne by the plant which one desires to cross. The flowers of a plant are either perfect or imperfect. Perfect flowers are those which possess both stamens and pistils; imperfect ones those which are devoid of one or the other reproductive organ or organs. The potato plant bears perfect flowers, and is of such simple structure as to render the task of crossing it comparatively easy (Fig. 205).

Structure of the Pistil.—The pistil of each flower is morphologically divided into two parts, *viz.*, the style and the stigma. Each potato flower bears but one pistil (Fig. 206), the style of which varies from six to nine lines in length, and from one-third to two-thirds of a line in diameter. Usually, the shorter the style, the fleshier it is. Some styles are greatly curved, and in some varieties there is a distinct spiral twist as in Up-to-Date and Factor. Others are perfectly straight. The two-lobed stigma also varies considerably in size, some being only slightly enlarged and somewhat cup-shaped, while others are considerably enlarged, having well-rounded lobes covered with short papillæ.

Structure of the Stamens.—The potato flower normally possesses five stamens, but occasionally four or six are noted. In some varieties six stamens are of quite frequent occurrence. The stamens have short, thick filaments with large, fleshy, erect anthers, which

Fig. 205.—Potato flower natural size showing stamens and pistil.

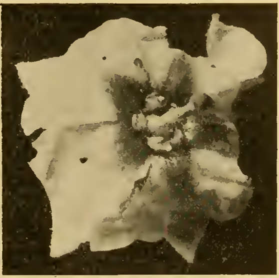

Fig. 206.—Potato flower with stamens removed showing naked pistil.

usually stand close together around the style, like a cone in the centre of the flower (Fig. 205). The anthers may vary from three to five lines in length and one to one and one-half lines in breadth, and about one line in thickness. The placenta, which divides the anther longitudinally into two equal cell-like compartments, is rather thick and fleshy. The halves or lobes of the anthers have small terminal pore openings for the discharge of the ripe pollen, which are produced on the inner surfaces of the cell. In many varieties, the anthers are so poorly developed that the terminal pores do not open, though they are not so undeveloped as to be devoid of pollen. In such cases, the membranous outer covering of each anther lobe or cell may be slit open, and the pollen grains scraped off into a receptacle by means of a scalpel, forceps or needle. Usually, however, such pollen is not viable, and one should, therefore, reject such varieties for pollen purposes. The color of the stamens varies greatly with different varieties. Some are a pale lemon-yellow, while others are a bright orange-yellow, with all the intergradations of color between these two. Only one

A B

FIG. 207.—Potato flower cymes. A shows three flowers which might be used for artificial pollination, though only the upper right hand bud is at the right stage. Cyme B has two buds at right stage.

A B

FIG. 208.—Cymes A and B after emasculation. Note protruding pistils in lower flowers of cyme A.

instance has come under our observation in which the color of the stamens did not answer to the above description, and that was in the case of a wild Mexican species, *Solanum cardiophyllum lanceolatum,* (Berth.) Bitter, where the anthers were chocolate-brown with a slight tinge of purple. Usually varieties with pale, lemon anthers do not produce pollen freely and, as a rule, it is not viable. A considerable variation has also been noted in the turgidity of the anthers, usually those of a pale lemon-yellow color are less turgid, and are more loosely arranged around the pistil. Often this looseness is in the nature of a distinct curving outward of the central portion of the anther, the tips of the anther clasping the pistil. Generally this type of flower has one or more defective stamens. On the other hand, it has been observed that some of those having a deep orange-yellow color, like those of *Solanum*

Fig. 209.—Emasculating the flowers.

Maglia, are so firm as to be almost coriaceous. Flowers of this class seldom, if ever, produce an appreciable quantity of pollen and, as a rule, it is not viable.

Artificial Cross-pollination.—The actual process of cross-pollinating potato flowers is comparatively simple; but since relatively few of our commercial varieties develop viable pollen, the percentage of success is usually small, unless the operator employs pollen from varieties that produce it freely and that is known to be highly viable.

The first step in the cross-pollination of the potato is obviously that of the selection of the parent plants. Strong, healthy plants should be chosen, of a variety possessing certain definite characters which it is desired to combine with certain other desirable characters of another plant. The next step is the selection and emasculation of the flowers to which pollen is to be applied, and the bagging of the same (Figs. 207 to 213).

The proper stage at which to emasculate the flowers is usually about 24 hours before the buds normally open. This stage is shown in figure 207-B. The only instrument necessary for the removal of the stamens is a sharp, pointed forceps (Figs. 209 and 212). To perform the operation, clasp the lower portion of the bud between the forefinger and thumb of the left hand and, with the forceps held in the right hand, slit open and push back the

Fig. 210.—A simple and handy pollinating kit.

corolla, after which the fleshy anthers can be easily and quickly removed by pressing each of them backward from the pistil until it snaps from its filament. Figure 206 shows a blossom from which the stamens have been removed in the manner described. It is usually desirable to emasculate as many flowers in each cyme as are at the right stage of maturity. All those that are too immature or mature should be removed before inclosing those that have been emasculated in a paper bag (Figs. 209 and 213). A one-pound bag, that is, a paper sack having a capacity mark of one pound is large enough for this purpose (Fig. 211).

The work of putting on the sacks can be greatly facilitated by perforating the tops of the sacks and running strings through them, prior to their use in the field, as shown in figure 211. Another feature that has proved satisfactory is that of inclosing with the flowers the young shoot on which the flower cyme is borne, or where this is not feasible, as much foliage as possible. The inclosure of the foliage serves a two-fold purpose, that of protecting the flowers by keeping the bag distended, and, in supplying moisture through leaf transpiration.

Fig. 211.—One pound paper bag ready for use.

The flowers are usually ready for pollinating one or two days after emasculation, depending upon the stage of maturity when emasculated and the character of the weather subsequent to it.

Salaman[15] and East[7] regard the covering of the flowers with bags as an unnecessary procedure and likely to cause injury to the pistil. On this subject Salaman says:

"All my work has been carried on without placing the flowers in bags. The reasons for not adopting special precautions were that, when bagged, the flower invariably drops; that bees and the like never approach a potato flower, though a small fly often lives in the bottom of the corolla; that the flower is constructed for self-fertilization; and that the quantity of pollen is so scanty as to render fertilization by the wind in the highest degree improbable."

East says:

"We may conclude that if we cut off all the uppermost cymes from the plant stems, and use for pollination only emasculated flowers of those borne next in order, the relative probability of our crosses being interfered with is negligible for all practical purposes. This removes the necessity of shutting out the light and air circulation by means of bags. It is also worthy of note that the chances of success are much greater if the calyx and corolla are not removed during emasculation, as the style is very slender and is likely to be injured."

While it is true that the pistil of the flower is easily broken off, and that few insects visit the flowers, it is not necessarily true that the inclosure of the emasculated flowers in paper bags causes any more of them to drop off than if left uncovered, provided the operator follows the suggestions given relative to including as much foliage with the flowers as is possible. The beneficial effect of the foliage has already been mentioned.

Method of Collecting and Applying Pollen.—Many methods have been pursued by the writer in collecting pollen, but none have proved as satisfactory as the one which is now followed. This

Fig. 212.—Jarring the pollen from the anthers on thumbnail.

Fig. 213.—Enclosing the impregnated flowers in paper bag and recording the cross.

method consists in gathering the flowers, as needed, from the plants which have been selected as pollen parents. When a large number of emasculated flowers are to be crossed and different pollen parents are to be used, it has been found expedient, as well as satisfactory, to collect a number of flowers of the varieties desired, which are at the right stage of development, that is, when the terminal pores of the anthers have just opened. Each lot collected is placed in a separate bag, the bags being similar to those used for inclosing the emasculated flowers. Each bag is properly labelled with the name of the variety or of its field number. In this way the operator may carry a considerable quantity of available material with him, which can be readily drawn upon as desired. When the pollen of any particular variety in the pollinating kit is desired, a flower is selected from the proper bag, the corolla is pushed back between the forefinger and thumb of the left hand and held in such a position that the anthers extend upward on the thumb nail (Fig. 212). After removing the pistil, the anthers are tapped sharply with the forceps, thus jarring the pollen out of the terminal pores, upon the thumb nail on which it is readily conveyed to the stigmas of the previously uncovered flowers. The cross is then recorded in a field note book, and its number placed on a string tag, which is attached to the pedicel of the flower cyme, after which the pollin

FIG. 214.—Seed balls eight days after application of pollen.

ated flowers are again inclosed in the paper bag, care being taken to include as much foliage as possible, and to avoid injury to the pistils. Generally the success or failure of a cross can be determined in a week from the date of applying pollen. Frequently the seed balls at this date will be two-thirds grown (Fig. 214). The rate of development is largely dependent upon two factors, *viz.,* the natural affinity of the plants crossed, and the amount of viable pollen applied to the stigma. As a rule, the paper bag should be removed in seven days. At this time the seed balls of all successful crosses should be inclosed in a loose cheesecloth sack, securely tied to the stem of the plant in order to keep it off the ground, or from breaking the flower stalk, when the plants begin to mature.

Percentage of Successes.—In some studies made by East (*l.c.* p. 36) to determine whether the uppermost, intermediate or lower flower cymes produced the largest quantity and the most viable pollen, he found that crosses, resulting from the application of pollen from such sources gave the following percentages of successes. Upper cymes 28 per cent; intermediate 52, and the lowest cymes 18 per cent. He states that these experiments were made on plants of a variety that naturally produced an abundance of pollen. In our own work there have been numerous failures as well as many successes. In the earlier years or between 1903 and 1908 very few successful crosses were made, certainly less than one per cent; but in 1909 the percentage of successful crosses was quite large. This was especially true in those cases in which pollen had been used from a variety known to produce a high percentage of viable pollen. In some instances, every flower pollinated bore a seed ball.

The data contained in the following table embody the results secured by the writer in 1909, while in the employ of the Vermont Agricultural Experiment Station and which were prepared and published in *U. S. Department of Agriculture Bul.* 195. A study of these data shows that 458 seed balls were produced from a total of 1,599 crosses. This represents an average of 28.6 per cent for the whole number crossed. When one takes into consideration the fact that a large percentage of these crosses were entire failures, indicating the use of worthless pollen, they can appreciate the fact that when the proper pollen is applied to a receptive stigma the percentage of successes will be high. If we analyse these data carefully, we find ample corroboration of the above statements. The following analysis is taken verbatim from the publication mentioned.

"A study of the table discloses some rather interesting data, particularly with respect to the behavior of seed-bearing plants when pollinated with different varieties. In the first cross recorded, Geheimrat Theil × Keeper, six flowers were pollinated and five seed balls were developed from which 502 tuber-bearing plants were produced. The same variety when mated with XX Early developed only one seed ball from 11 pollinated flowers, and this did not produce a single tuber-bearing plant. When crossed with *Solanum Maglia*, a wild South American species, it failed to set fruit; and the same negative results were obtained when

Record of potato crosses made at Burlington, Vt., in 1909.

Parentage of cross	Number of flowers crossed	Number of seed balls developed	Percentage of success	Number of tuber-bearing seedlings	Average number of seedlings per seed ball
Geheimrat Theil × Keeper........	6	5	83.3	502	100.4
" " × "XX" Early...	11	1	9.1	0	0.
" " × *S. Maglia*......	3	0	0.	0	0.
Sophie × Keeper........	20	16	80.	2244	140.3
Sophie × Fuerst Bismarck	4	0	0.	0	0.
Sophie × Empire State..	8	0	0.	0	0.
Sophie × Garnet Chili...	4	0	0.	0	0.
Sophie × Irish Seedling..	4	4	100.	707	176.8
Sophie × Venezuela.....	3	0	0.	0	0.
Prof. Maerker × Apollo........	12	9	75.	275	30.6
Prof. Maerker × Early Silverskin	15	15	100.	555	37.0
Prof. Maerker × Keeper........	13	12	92.3	326	27.2

pollen of the unnamed Mexican species of Solanum was used. We know that *S. Maglia* produces pollen very sparingly and that frequent attempts to germinate the pollen in the laboratory have been unsuccessful. The Mexican species is known to produce viable pollen in abundance, however, so that in this case the failure to set fruit was probably a clear example of non-affinity. The next female parent, Sophie, crossed with Keeper, gave excellent results. Sophie is a German variety possessing qualities of vine and tuber strongly resistant to late blight. From 20

FIG. 215.—A South American variety with clusters of naturally fertilized seed balls.

pollinated flowers 16 seed balls were developed. The seed from the 16 seed balls produced 2,244 tuber bearing plants, or an average of 140.3 plants per berry. The 4 pollinated flowers of Sophie × Fuerst Bismarck failed to develop a single berry. A similar result was obtained from 8 flowers pollinated with Empire State and from 4 pollinated with Garnet Chili. Sophie × Irish Seedling produced 4 seed balls from the 4 flowers pollinated. The seeds from these berries gave 707 tuber bearing plants, or an average of 176.8 plants per berry. Three flowers pollinated with Venezuela failed to set fruit. It is clearly evident that the varieties Fuerst Bismarck, Empire

State, Garnet Chili and Venezuela either did not develop viable pollen or the pollen tubes were unable to reach the ovules of the flower. It is known that all of these varieties produce pollen sparingly, and it is probable that an insufficient quantity of viable pollen was present to effect the cross.

"In the first cross of the third seed parent, Professor Maerker × Apollo, both the seed and pollen parents are of German origin, the latter being one of the most disease-resistant varieties in the collection. Nine seed balls are recorded from 12 flowers pollinated and 275 tuber-bearing plants

Fig. 216.—An Irish Cobbler plant bearing several clusters of seed balls the result of artificial application of pollen. One cheesecloth sack removed to show the berries.

were obtained from this lot, or an average of 30.6 plants per berry. Fifteen flowers pollinated with pollen from Early Silverskin produced 15 seed balls, from which 555 plants were obtained, an average of 37 plants per berry. When crossed with Keeper, 12 seed balls were developed from 13 flowers and these gave 326 plants, or an average of 27.2 plants per berry. Pollen from Rand's Peachblow proved ineffective.

"It is interesting to compare the results from the two crosses, Sophie × Keeper and Professor Maerker × Keeper. In the first instance the percentage of success is 80 and in the latter 92.3. Carrying the compari-

Fig. 217.—Several seed balls showing different views of the fruit or berry, also the position and relative size of the seeds. Half size.

son farther, however, we find that the first cross averaged over 140 plants per berry, while the latter averaged only 27.2. These data make it at once apparent that some varieties develop fewer ovules than others."

Gathering the Seed Balls.—The seed balls should be allowed to remain on the plant until they are mature (Figs. 215 and 216), or until danger from frost makes it desirable to gather them. When gathered they should be placed in a moderately warm room to insure thorough ripening. Unless the cluster of seed balls is large, they are allowed to remain in the sack until they are thoroughly ripe. Most seed balls, when ripe, are usually of a pale lemon-yellow color; but some of the foreign varieties, or those

Fig. 218.—Seedling potatoes ready to be potted off or pricked out into flats.

having foreign blood in their parentage, are of a purplish-black color.

Removing the Seeds.—The usual practice is to remove the seeds as soon as the seed balls are ripe (Fig. 217). This is most easily accomplished by crushing the seed balls into a pulp, and dropping them into a vessel of water in a warm room. They should be allowed to remain in the water for a few days, or until sufficient fermentation takes place to cause the pulp to rise to the top. Frequent stirring of the contents of the vessel during this time will hasten the separation of the seeds from the pulp. When the seeds are largely separated from the pulp, the latter may be floated off the top of the vessel by running water into it; after this the water can be poured off through a strainer or a cheesecloth to collect the seeds, which should then be dried in a moderately warm room. When dry, they should be placed in a packet and properly labelled.

In this condition, they may, if so desired, be held several years, without material lessening of their viability.

Method of Growing Seedlings.—Various methods may be employed in the growing of potato seedlings. The one practised by the writer is that of sowing the seed in flats or earthen seedpans in the greenhouse about the last of March, the soil used being a light, sandy loam of moderate fertility. The seeds are sown in

Fig. 219.—Setting out the young potato seedlings. This particular lot is much smaller than the average.

about the same manner as pepper or tomato seeds, and covered to a depth of about one-eighth of an inch. Under favorable conditions, well-matured seed will begin to germinate in from 4 to 6 days, and in 10 days to two weeks most of the seeds will have started to grow. In from four to five weeks they will be ready to transplant (Fig. 218) to other flats or to be potted off into two and one-half-inch paraffin paper pots. With careful attention to watering and room temperature, these plants should be ready to transplant into the open about the last of May or first of June (Fig. 219). At this time, if well grown, they should be stocky and thrifty plants of from 4 to 5 inches in height. A night temperature of from 55 to 60 degrees F., with a rise of 20 degrees during sunshiny days and 10 degrees in cloudy ones, will insure a moderate and healthy development of the plants in the greenhouse.

The foregoing outline of procedure is not intended to convey to the reader the impression that a greenhouse is necessary to start seedling potatoes. They can be grown in a hotbed, or they may be started in the living room of the house or anywhere else in which there is sufficient heat and light, after they germinate. The same methods can be followed as for tomatoes or peppers. It is desirable to start the potato seedlings early in order to give them a long growing season, so as to insure good tuber development the first season, thereby making it possible to discard the undesirable ones and thus reduce the number to be tested the ensuing year.

Field Culture of the Seedlings.—Do not make the mistake of planting the seedlings too close. Long experience has demonstrated that a spacing of 30 by 36 inches is none too much. The rows are spaced three feet apart and the plants 30 inches in the rows. Even at this distance, it will often be found that many of the plants will more than cover the space allotted to them; their long, tuber-bearing stolons will intermingle, making it difficult to distinguish whether the tubers belong to the one or the other of the two adjacent plants in the row. The culture accorded the seedling plants, after transferring them to the field, is not essentially different to that which should be given to commercial varieties. Every effort should be made to provide them with as good growing conditions as possible. Thorough spraying is essential to protect the foliage against insect and fungous pests, in order that an intelligent reading may be obtained on their behavior the first season. Seedlings from different crosses frequently show great variation in habit of growth and vigor of vine, making it possible to obtain a fairly accurate reading from the F_1 generation (first year seedlings) of the value of different varieties as parent plants.

Harvesting the Seedlings.—In many respects the harvesting of the seedlings is the most interesting feature of this work. The striking differences that are met with in seedlings of different parentage, or even of the same parentage, are sometimes rather puzzling. One seedling may produce rough, uneven tubers, while the adjoining one may have smooth ones (Figs. 220 and 221). In like manner, the shape of the tuber may vary in every conceivable manner; some being so knobby as to be absolutely worthless, or so deep-eyed as to give the surface of the tuber an irregular appearance. Similarly, all gradations in color may be noted. With the harvesting of the seedlings comes the first, real, selective process connected with the raising of seedling potatoes. All plants having irregular tuber progeny, deep-eyed, undesirable in color, or that are too numerous, should be immediately discarded. Only those that are of good shape should be retained (Fig. 221). Our present practice is to take notes on the number, size and shape of tubers, frequency and depth of eyes, color of skin, and general desirability

Fig. 220.—A decidedly unpromising first year seedling.

of the tubers as a whole. This information, while in nowise exhaustive, affords a basis for the study of inheritance of certain tuber characters, and may furnish important data on the transmission of parental characters. Such data, if properly interpreted, enables the breeder to carry on his work with a greater degree of intelligence; and may even permit him to predict, with more or less accuracy, what may be expected from the progeny of certain parents.

As each selection is made in the field, a number is assigned to it in the notebook. This number is also written on a string tag, with a perforated, detachable stub, which is inserted in the selected hill and serves to indicate those which are to be saved. Each selection is picked up separately in small cotton or gunny sacks or in stout manila paper bags, the stub, with number affixed, is torn off and placed in the bag, while the string tag proper serves to tie the bag, and indicates by the number on the bag which seedling selection it is. The stub inside is a safeguard against the loss of the outer tag or the number affixed thereto. Usually no weights are taken of first year seedlings, except in the case of extremely high-yielding hills. The highest-yielding seedling thus far produced by the writer weighed over nine and one-half pounds. The following year it has been our practice to grow five plants each of

FIG. 221.—A promising first year seedling.

the seedlings; occasionally, however, when the seedling seems unusually promising, ten plants are grown. Generally, whole tubers are planted in order to insure a perfect stand, besides effecting a considerable saving in time which would necessarily be involved in the cutting of a large number of small lots of seed. The five plants are sufficient to study the habit of growth of the seedling, its resistance to disease and its tuber development. As they are harvested, the same rigorous selection is practised as in the first season. From this period on, larger plantings are made of the more promising ones (Figs. 222 and 223). Usually it is not safe to introduce a seedling until it is five or six years old; although there are exceptions to this statement, as in the case of the Burbank and Early Ohio, which were three and four years old, respectively, when first introduced.

The growing of seedling potatoes on a large, or even on a moderate scale, is an expensive proposition, and offers little compensation to those engaged in the development of new varieties.

POTATO IMPROVEMENT BY SELECTION

The improvement of the potato by selection is a field of endeavor in which every grower interested in the problem of increased production per acre can engage. While, as has been previously

Fig. 222.—Taking notes on seedling potatoes, Presque Isle, Me., 1918. Note two diseased seedlings in the foreground.

noted, the limitations in selection are much more restricted than in the case of breeding, in which sexual reproduction plays an important rôle, it is, nevertheless, by no means as limited as might be supposed, as more or less variation already exists within most of our cultivated varieties.

These variations express themselves in a multiplicity of ways, such as uniformity in size and shape of tuber and the number produced per plant. Some plants may produce 2 or 3 large tubers, others the same number of large tubers but with a half-dozen or more small ones, while still others may be found producing from 6 to 10 or more medium-sized merchantable tubers with practically no small ones. It is plainly evident that the progeny of such plants as those last described are more desirable than those of the other two.

In like manner it is conceivable that certain variations may occur in the plant itself. Such variations may be expressed in any of the following attributes of the plant proper: 1. Disease resist-

Fig. 223.—Taking notes on potato seedlings at Presque Isle, Me., 1918. Note floriferous habit of plants in central portion of picture.

ance. 2. Drought resistance. 3. Heat resistance. 4. Greater vigor. 5. Greater adaptability to peculiar environmental conditions of soil and climate.

It is quite possible to conceive of other variations which might be well worth considering. It is the business of the selectionist to detect and isolate these variations and, through careful testing, determine whether they are heritable variations transmissible from one generation to another, or whether they are merely accidental variations due to a larger supply of moisture, plant food or some other external factor.

Early Attention to Selection.—That the subject of selection is not a new one, and that its possibilities were recognized by earlier investigators, is amply substantiated by the following examples.

In 1795, Anderson,[1] in a communication to the potato Committee of the Board of Agriculture of Great Britain, suggests the possibility of greatly increasing the yield of potato varieties by selecting seed from productive plants, and growing the progeny of each selection separately, in order to ascertain which was best. That he thoroughly understood the principles of selection, as they are known today, is clearly evident, because he was careful to suggest that some productive plants will not transmit this character to their progeny. While Anderson does not actually present experimental data to substantiate his views, he makes the assertion that he can "speak from experience with great certainty; and can affirm that, by a careful attention to these circumstances, a farmer in a very few years will, in many cases, more than double the amount of his average crop of potatoes, soil and culture being the same."

One of the earliest experiments that has come to notice is one which was carried on by Hallet[13] between 1868 and 1882. His account is as follows:

> "In the case of the potato, I have also applied my system, starting every year with a single tuber, the best of the year (proved to have been so by its having been found to produce the best plant) for fourteen years. My main object here has been absolute freedom from disease, and these potatoes are now descended from a line of single tubers, each the best plant of the year, and absolutely healthy; and concurrently with the endeavor to wipe out all tendency to disease, I have always kept in full view the point of increasing productiveness. The result may be thus shortly stated: Dividing the first twelve years into three periods, the average number of tubers upon the annual best plant selected was, for the first period of four years 16; for the second period of four years 19; for the last period of four years 27; or nearly double the number produced during the first series of four years. And if, as I might very fairly have done, I had confined the first period to the first three years (instead of four), the last period would have shown an average of 27 tubers against 13 in the first period, or more than double."

The evident care with which this experiment was conducted, and the continued selection of the best plant based on freedom from disease and productiveness, would seem to indicate that Hallet had definite clear-cut ideas concerning the advantages of selection in building up vigorous and productive strains.

Observations of Carrière.—Carrière[5] in discussing variations in the potato says:

> "The potato furnished us with examples of modifications just as remarkable as those which we have reported for beans and for corn...... Every year, in reality, when we harvest the tubers and wish to conserve the purity of the variety, we are obliged to purify, that is, to make a choice and reject those which, as we say, have degenerated....The modifications in the potato may occur equally well in the underground parts; that is what has happened in the variety called Pousse-debout.

The name Pousse-debout has been given to this variety because the tubers which it produces, instead of being placed flat or nearly so in the soil, are arranged one against (upon) the other, much like pieces of wood are disposed for transformation into charcoal."

It is further stated by Carrière that the Marjolin potato is a variety possessing the peculiar quality of never flowering, and of being very early; but, notwithstanding this fact, it is continually producing plants which flower and produce seed, and which, owing to this fact, are not as early as the parent plant. Carrière also observed transformations or variations in color of flowers, shape of tubers, and season of ripening in the variety Chardon. He remarks that these variations in the Chardon are rather odd, because it had long been under his observation without having previously shown any variation whatsoever.

Transmission of Productivity.—In all the selection work, carried on by Goff[11] in 1884 and 1885, he demonstrated that tubers from productive plants gave larger yields than tubers from unproductive plants, the total gain being a little more than 24 per cent.

Fischer's Work.—In 1897 Fischer[10] began some selection work with the potato in which variations in productiveness, shape and starch content of tuber, as well as habit of growth of the plant were studied. Fischer's work was very largely carried on in pots, under as nearly uniform conditions as possible, and yet the variations in the tuber yield were in some instances in the ratio of 100 to 233.

The individual deviation within the variety itself was found, in the case of the Saxon onion potato, to be associated with certain definite characters; for example, flat-round tubers, rich in starch, were found to be correlated with a more or less restricted vegetative growth and tuber yield. Long tubers, poor in starch, were, on the other hand, found to be correlated with strong vegetative growth and a high tuber yield, as compared with that of the flat-round ones. This is strikingly illustrated in the following data, which give the relative proportion of dry stalks and tubers from the two types of mother tubers:

Strain I. Flat-round mother tubers, rich in starch (18.68 per cent.); dry stalks 100 per cent., tuber yields 100 per cent.

Strain VII. Long mother tubers, poor in starch (11.83 per cent.); dry stalks 14.5, tuber yields 204 per cent.

Fischer also noted the deviations within these types, and presents data showing that, while a considerable deviation occurred, the maximum yield from the flat-round type did not approach very closely to the minimum yield of the long type. These data show the following deviations:

Strain II. Flat-round tubers, rich in starch; dry stalks 100 per cent; tuber yield 100 per cent.

Strain III. Flat-round tubers, rich in starch; dry stalks 114.5 per cent; tuber yield 167 per cent.

Strain V. Long tubers, poor in starch; dry stalks 142 per cent; tuber yield 216.7 per cent.

Strain VI. Long tubers, poor in starch; dry stalks 175.5 per cent; tuber yield 233.3 per cent.

It is observed that the plants from the flat-round tubers were shorter jointed and matured earlier than those from the long tubers. This would indicate that the latter represented a later maturing strain.

Productive *vs.* Unproductive Hills.—In December, 1904, Eustace[8] reported a rather interesting study on the behavior of "productive *vs.* unproductive hills." When harvesting the 1903 crop, Eustace selected the progeny of 125 productive plants and an equal number of unproductive plants. Weights were taken of the tubers from each of the 250 plants selected, a record being made of each; but after the weights were taken, no effort was made to keep the progeny of the productive hills separate; in other words, the experiment resolved itself into a mass selection. The unproductive hills were handled in a similar manner. In the following Spring, 10 rows of 232 plants each were planted from the productive lot, and 5 rows from unproductive. The resultant production was at the rate of 362.25 bushels from the productive hills and 339.16 bushels per acre from the unproductive. The significant feature of Eustace's data is to be found in the deviation which occurred between the individual plants in the 1904 crop. The data shows the deviations were almost as great as in that of the original stock of the previous year. The 1904 deviations were 11.9 ounces or 39.18 per cent as against 9.37 ounces or 39.44 per cent in the 1903 crop. In this connection Eustace says:

"That the variation was not materially reduced by the uniform conditions under which the experiment was made was a surprise. The conclusion is that factors, which are apparently unimportant, produce wide differences in yield."

From our present knowledge of the behavior of individual hills of potatoes, these data are not at all surprising; and, even though

Eustace's studies had been made with the progeny of the individual hills instead of in mass selection, it is questionable whether the deviations would not have been just as great as those noted.

At the annual meeting of the American Breeder's Association, in 1907, Waid[18] reported the results of similar studies to those of Eustace. This work was conducted at the Ohio Experiment Station during the seasons of 1904 to 1906 inclusive. Seed was selected from productive and unproductive plants in the fall of 1903. The three-year average from high- and low-yielding plants was found to be 1.38 pounds for the former, and 0.73 pounds for the latter, or a difference, in favor of the high-yielding plants, of over 89 per cent. A comparison between the productive plants and those grown from the common or unselected bin-run stock, showed a gain of over 25 per cent in favor of the productive stock.

The most interesting feature of Waid's data is brought out by a comparison of the average weight of the tubers from the ten high-yielding hills selected in 1903, and the three-year average from these original hills. The average of the ten original hills was 2.38 pounds per plant, whereas the three-year average is only 1.38 pounds or a decrease of almost 42 per cent. The inference suggested by the data is that, in the selection of high-yielding hills, one is not at all certain what proportion of the hills are likely to maintain their seemingly productive character. Recent observations regarding the behavior of high-yielding hills lead to the belief that less real progress will, as a general thing, be made by selecting the very high-yielding hills. In fact, there is considerable evidence accumulating which would indicate that the practice is not to be recommended. In this connection, East's[7a] statement with reference to his experience with high- and normal-yielding hills from a select strain of Rural New Yorker No. 2 would seem to offer supporting evidence. He reports his observations as follows:

"In 1906 we had in stock a supply of the well-known variety Rural New Yorker No. 2, which had been grown from a single hill in 1904. A selection of tubers from the five best-yielding hills was planted in 1907, and compared with five normal hills producing only one-half as much. The five best-yielding hills averaged 1,200 grams (2 pounds 10 ounces) of tubers per hill, with an average set of eight tubers. The check hills averaged 600 grams, with a set of four tubers each. Ten hills were planted in each case, two tubers being planted from each hill. In every case, pieces of about the same weight were planted. The yield from the high-yielding selections was at the rate of 101 bushels per acre, while the yield from the check hills was at the rate of 128 bushels per acre."

The year following, the progeny from the high-yielding strains averaged 96 bushels per acre, and that from the low-yielding 90 bushels. In 1909 the yields were, respectively, 115 and 120 bushels per acre. The average yield for the three seasons was at the rate of 104 bushels per acre from the high-yielding and 113 bushels from the low-yielding strain.

In a more recent article Berthault[4] summarizes his observations upon sexual reproduction, which, roughly translated, are as follows:

"1. That the form of the tuber is not a stable character in our cultivated varieties.

2. That the color, generally maintained through asexual propagation, sometimes varies.

3. That the depth of the eyes, a character almost always maintained in asexual reproduction, also offers, without apparent cause, examples of bud variation."

Selection Methods.—While the preceding discussion on "potato improvement by selection" has touched, in a more or less general manner, the processes of selection practised by those whose investigations have been cited, it has not dealt with specific methods, and their *"modus operandi."* Since the publication of the paper on "potato breeding and selection,"[17] the views regarding the importance of the "tuber-unit" as compared with the "hill selection" method of seed potato improvement, have been somewhat modified, as will be noted in a subsequent portion of this chapter.

The Tuber-Unit Method of Selection.—The tuber-unit method of seed selection was first advocated by Webber[19], in 1908, since which time it has been rather widely practised by selectionists. It consists in planting selected tubers in such a way that the plants from each tuber will be definitely isolated from each of the other tuber-units. The tuber is cut lengthwise, through its central axis, into four as nearly equal parts as possible, aiming in all cases to cut through the cluster of eyes surrounding the terminal one. The quarters are planted consecutively, and a double space is left between the four units of each tuber, in order that they may be easily distinguished from one another. In selecting these tubers from the field or bin, the operator is supposed to select only those that conform to the type of the variety, that are free from all external diseases, and that weigh from 5 to 9 ounces. Smoothness of tubers and shallowness of eyes should be considered when making selections. No tubers should be taken that show the least tendency to running out, as indicated by a pointed seed or stem-end or a constricted centre, usually referred to as waisted. As many tubers should be selected as the grower thinks he can properly care for and make the necessary observations. Those selected should receive the usual treatment advocated for scab disinfection before being planted. While the original directions specify that the tubers should be cut into four equal longitudinal sections, our experience has shown that, in the case of a long cylindrical tuber or even a moderately long tuber, as, for example, the Early Rose, Early Ohio, Beauty of Hebron and Burbank, it is much better to cut the two longitudinal halves crosswise than to halve them lengthwise. The reason for this is quite apparent. To divide the halved tuber lengthwise gives a long, slender seed piece which is much more likely to dry out or decay, according as to whether the soil is too dry or too wet, while the seed piece is germinating. To divide it crosswise gives a short, blocky seed piece which is, in every respect, better fitted to successfully withstand unfavorable soil conditions after it is planted. The claim that greater uniformity in the four seed pieces was secured by the longitudinal quartering of the tuber, has not been substantiated in our own studies.

When the plants are about full grown, each set of fours should be carefully studied; and those which are most uniform, vigorous and healthy, and which conform most nearly to the type of the variety should be marked. Later in the season the tuber-units should again receive careful study for the presence of diseased or abnormal plants. The appearance of the plants at this time, or even at the earlier period, will no doubt present many marked differences between the various units. In all probability, as great variations will be noted as those shown in figures 224 to 229. At harvest time each unit, that is, each set of four plants, should be dug by hand and the progeny of each carefully examined. Many of those which were marked as promising from the appearance of the plants will be found undesirable from the tuber standpoint. They will either have given a light yield, or the tubers will be found lacking in uniformity as regards size or type, or both. Select those which have produced a reasonable number of marketable tubers with a small proportion of seconds and culls, and that are desirable in shape and color, bearing in mind that the heaviest producing units are not necessarily the most desirable ones to save. Place the tubers from each unit selected in separate sacks, and give each a

Fig. 224.—A healthy normal tuber unit of the Norcross variety in 1911.

FIG. 225.—1912 product from five tubers produced by the 1911 tuber unit shown in 224. Large pile on left represents the primes, those on the right culls. The large number of culls is attributable to unfavorable conditions for the Norcross variety.

field number. In labelling the sacks, use the perforated string tag mentioned in the handling of seedling potatoes. While it is not absolutely necessary, it is, on the whole, rather desirable to make a record of the number and weight of large and small tubers produced by each unit selected, because it is only by this means that one can really determine the true value of each selection. The following season, plant the progeny of each unit in a trial row by itself, but not, necessarily, on the tuber-unit basis. When the plants are full grown, they should again be studied, and all selections which do not show a reasonable degree of uniformity of

Fig. 226.—A weak and probably mosaic-infected tuber unit of the Norcross variety, 1911. From same lot of seed as the healthy unit shown in 225.

Fig. 227—1912 product from five of the best tubers produced by the 1911 weak tuber unit. Primes on left, culls on right.

plants, or that are lacking in vigor, or are diseased, should be marked for rejection. A second examination should be made toward the close of the growing season, and the same notes made as in the preceding inspection. At harvest time, each progeny row should be dug separately, and only those which are productive, and reasonably uniform in size, shape, and conformity to varietal type should be saved. From this period on it should be possible to eliminate all but one or two of the very best strains, which should be grown on a field basis the following year in order to increase the seed stock.

Hill Selection.—The only difference between hill selection and the tuber-unit method is, that in the one case a start is made with the tuber as the unit, whereas in the other, the hill or individual plant is the unit. In hill selection the growing plants are carefully scanned for the purpose of picking those which are most promising from the standpoint of health, vigor, and conformity to type (Figs. 230 to 236). The ideal time for the first examination is when the

Fig. 228.—A partial view of a healthy Irish Cobbler tuber unit.

Fig. 229.—A weak mosaic-infected Irish Cobbler tuber unit. From same lot of seed as the healthy unit.

plants are in bloom, or, in the event that the variety does not bloom, when the plants have reached their full size. As in the case of the tuber-unit plants, a later examination should be made in order to detect diseased or prematurely ripening plants. Just prior to harvesting the field, all the marked plants should be dug by hand and the progeny of each carefully examined. The same procedure should be followed from this point on as that outlined for the tuber-unit work.

FIG. 230.—A field of Russet Burbank potatoes. The two taller plants in center indicated by the arrows are "run-outs" or degenerate plants. Carbondale, Col. (Sweet ranch.)

FIG. 231.—Progeny from one of the "run-outs." These tubers should never be used for seed stock.

In general, the chief value of a large proportion of the selection work that is now carried on lies not so much in the fact that new strains have actually been secured, or that more productive strains have been developed, but rather that the varieties have been purified with respect to varietal mixtures, and to fungous pests of the vine and tuber. It is also due in some measure to the elimination of the weak, unproductive plants, and of obscure, physiological troubles. If the selectionist is fortunate enough to secure desirable variations from the parent plant that are transmitted from one generation of tubers to the other, a further gain has been secured.

The work of Fischer would indicate that a high starch content is associated with shape of tuber. This factor is one which the ordinary man would be unable to detect without the aid of the chemist. The simpler phases of selection work may be successfully undertaken by any live up-to-date grower who is sufficiently interested to establish a seed plot. To those who do not care to practise selection on the individual plant basis, mass selection offers an inviting field.

Fig. 232.—Progeny from a good Russet Burbank plant. These tubers will make excellent seed stock.

Mass Selection.—The first steps in mass selection are identical with those practised in hill selection. The field from which the selections are to be made is carefully gone over prior to harvesting the crop; all desirable looking plants are dug by hand and selections, based on the number, shape, size, uniformity and quality of the tubers produced are made from them. At this point the processes cease to be identical, as in mass selection the tubers from the hundred or thousand or more plants chosen are all thrown together, and are subsequently planted and grown in much the same manner as the general run of seed stock would be handled. While mass selection does not permit of building up or isolating strains of a variety, it does very largely eliminate the weak, unproductive and diseased stock. The advantage of mass selection over hill selection is that it does away with the necessity of handling a large number of selections separately, thereby very greatly lessening the amount of work connected with such a method of seed improvement and for that reason will commend itself to many a grower who could not be induced to practise either of the two other plans. It is believed that mass selection is a step in the right direction and growers should be encouraged to adopt it.

The Seed Plot.—To those who are unwilling or unable to devote the necessary time involved in the practice of any of the selection methods discussed, there is still another way in which the quality of the seed stock may be maintained or actually improved. This method consists in planting a sufficient number of rows in the potato field with well-selected seed, and then going through them carefully several times during the growing season for the purpose of detecting and removing any possible varietal mixtures, and all the weak and diseased plants. When harvested, the progeny from these rows should be stored in a separate bin and used for planting the commercial field next year, after having again selected the best stock for the seed plot. The actual work involved in the conduct of such a seed plot is comparatively slight, while the increased yields are relatively large. It is not necessary to be able to recognize potato diseases in order to maintain such a seed plot. All any grower needs to know is enough to be able to recognize plants that are not normal for the particular variety grown. If all abnormal plants are removed, the chances are more than even that most, if not all, of the diseased plants will be removed.

Fig. 233.—Progeny from a good Russet Burbank plant, but the tubers are not as uniform in size and shape as those shown in Fig. 232 and will not make as good foundation stock.

The selectionist should always maintain a seed plot in which to test out his selections. As a rule, the seed plot should be planted at a later date than that of the commercial field (Figs. 235 and 236), with a view to securing somewhat immature and medium-sized seed stock.

Seed Potato Development Work.—While in one sense this work does not embody any new ideas, it is only recently that any attempt has been made to commercialize the results secured. It has long been known that different lots of seed of the same variety obtained from growers in various localities in a state, or even in a county, show surprisingly wide variations in yield. Until recently, no serious attempt had been made to take advantage of this situation by securing and disseminating these high-yielding strains. Prof. W. S. Blair, Superintendent of the Dominion Experimental Farm of Kentville, N. S., was one of the first investigators to call our attention to this subject, when he mentioned the results of some studies upon a number of strains or lots of the Garnet Chili, Green Mountain and Irish Cobbler potatoes which he had carried on under the direction of W. T. Macoun, the Dominion Horticulturalist of Canada, during the years 1915 to 1917, and reported by Macoun in 1918.[14] The difference between the highest- and lowest-yielding strains of eight lots of Garnet Chili potatoes in 1915 was 204 bushels. In 1916 the difference in yield of the same stocks was 144 bushels; and in 1917 it was 225 bushels. Ten lots of Green Mountains, tested in 1916, showed a maximum variation of 132½ bushels; while in 1917 the difference was 147 bushels per acre. In the 17 lots of Irish Cobbler, tested in 1916, there was a variation of 142 bushels; while in 1917 the difference amounted to 172 bushels per acre.

Fig. 234.—Progeny of a single plant of the Russet Burbank potato. Mother tuber at apex. Grown by the Crystal River Land Co., Carbondale, Col.

Some unreported experimental studies in 1919 and 1920 in Wisconsin and Minnesota similar to those conducted at Kentville, Nova Scotia, fully corroborate the Canadian results, thereby justifying a growing conviction that this field of experimentation offers greater possibilities for immediate results than does the tuber-unit or hill selection methods. The location of high-yielding strains by this method of comparison as to the productivity and general desirability of given strains

FIG. 235.—High grade field-selected table and seed stock. Courtesy of Lou D. Sweet.

FIG. 236.—High grade field-selected table and seed stock. Courtesy of Lou D. Sweet.

enables the experimentor to immediately place a goodly quantity of this varietal strain in the hands of those who are interested in the production of high grade seed potatoes. Furthermore, it is reasonable to assume that more certain and lasting results should be secured from the use of such a strain for the development, through selective processes, of a still more desirable seed stock.

QUESTIONS ON THE TEXT

1. Give the author's definition of breeding and selection.
2. What are the limitations in breeding?
3. What are the limitations in selection?
4. When did potato breeding begin to assume importance in America and Europe?
5. With the exception of Goodrich, what was the chief consideration in the minds of American potato breeders regarding new varieties?
6. Name some of the more prominent of the nineteenth century American potato breeders.
7. What was Goodrich's notion concerning the effect of long continued asexual propagation upon the vigor of the potato plant?
8. What remedy did he propose? What stocks did he use?
9. What was the most important variety he produced?
10. How many seedlings did he grow?
11. In what respect was Goodrich's type of potato breeding lacking?
12. What influence did Goodrich exert through the agency of the press?
13. By whom and at what date was the Early Rose originated? Give its parentage.
14. What other varieties did Bresee originate?
15. In what way does Pringle's work rise above that of most other American potato breeders?
16. At what price per pound did Pringle contract to produce hybridized potato seed?
17. Give substance of quotation from Pringle's letter to Fenn.
18. Name some of the varieties originated by Brownell.
19. Name some of Rand's seedling productions.
20. Mention some of the varieties originated by Alexander.
21. What varieties did Gleason and Heffron originate?
22. Give a brief resumé of the origin of the Burbank Seedling.
23. How does Burbank's achievement compare with that of Goodrich's?
24. In what way did Goodrich's successors profit by his work?
25. What variety did Alfred Reese produce? Where is this variety most extensively grown at present?
26. What varieties did E. L. Coy originate? Give parentage of his Early Beauty of Hebron.
27. Review the work of Carman.
28. What varieties did Bovee produce?
29. What varieties did Craine give us?
30. What varieties did Van Ornam originate?
31. Who was Great Britain's pioneer potato breeder? Review his work.
32. Review letter of Robert Fenn to Pringle, January 27, 1876.
33. When did Fenn make his first crosses and what varieties did he use?

34. Give the parentage of Clark's Magnum Bonum and some of the characteristics it possessed which helped to make it famous.
35. Give the name of the variety that made Archibald Findlay so famous as a plant breeder.
36. What name stands out most prominently among the plant breeders of France?
37. What did Wilhelm Richter accomplish in the improvement of the potato in Germany?
38. Compare catalogue descriptions of the new potato introductions of the present period with those from 1857 to 1890.
39. How do European activities in potato breeding in the twentieth century compare with those of the nineteenth century?
40. At what prices did early productions sell?
41. What are the difficulties confronting the potato breeder at the present time?
42. What does East say about the flowering habits of our commercial varieties of potatoes?
43. How does the author's opinion compare with East's deductions on the flowering habits of potato varieties?
44. How do varieties differ in production of viable pollen?
45. What was the character of the four American varieties found to produce a dependable supply of viable pollen?
46. What two foreign varieties are mentioned as being good pollen parents?
47. What assertion did Salaman make with reference to male sterility?
48. Describe the structure of the pistil and the stamens of the potato flower.
49. What relation between color of stamens and development of pollen?
50. Give relation between turgidity and male sterility.
51. What does the author say regarding extreme turgidity of the stamens bordering on the coriaceous?
52. What should be the first and second steps in artificial cross-pollination?
53. What is the proper stage at which to emasculate potato flowers?
54. Describe method employed by the author in emasculation.
55. What covering is recommended to inclose the emasculated flowers?
56. What particular advantage is there in inclosing foliage with the flowers?
57. What interval should usually be allowed between emasculation and the application of pollen?
58. What methods of collecting and applying pollen and recording were adopted by the author?
59. How long does it usually take before one can determine whether the cross is a success or failure?
60. When should the seed balls be gathered? How kept?
61. What is the simplest method of removing the seeds from the seed balls or berries?
62. What directions are given for growing seedlings?
63. How long does it take good potato seed to germinate?
64. At what distance should the seedlings be spaced in the open field?
65. What notes should be taken on each individual plant when harvesting and how should those saved be recorded?
66. How should the subsequent testing of the seedlings be conducted?
67. How many years should a seedling usually be tested before introducing it? What exceptions are noted?
68. What are the variations sought in selection?
69. What is the tuber-unit method of selection?

70. What is the hill selection method? In what respect does it differ from the tuber-unit method?
71. What is meant by mass selection? How does it differ from hill selection? Is it a desirable practice?
72. What other method of seed improvement is open to the grower?
73. How does it compare with the preceding methods?
74. What is meant by seed potato development work?

QUESTIONS AND EXERCISES SUGGESTED BY THE TEXT

1. What is the usual custom of local growers regarding seed selection of potatoes?
2. What improved methods are tried by the best?
3. What results have been secured locally from tuber-unit selection?
4. What from hill selection?
5. When harvesting potatoes, weigh the yields of some of the best and poorest hills.
6. If possible, compare the relative yields in a hill-to-row test.

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CHAPTER XXII

CLASSIFICATION AND DESCRIPTION OF COMMERCIAL VARIETIES

WITHIN the past few years a distinct advance has been made in the classification of American varieties of potatoes into groups or classes having certain distinctive characters of vine or tuber. This step was made necessary through an increasing tendency on the part of some seedsmen to give old varieties new names, thereby adding greater confusion to that which ordinarily obtained. Although but a few years have elapsed since the group classification was really undertaken in the United States, it has already exercised a very beneficial effect upon the introduction of new varieties. In fact, some of the seedsmen have modified their list of seed potato offerings so as to comply in a very acceptable manner with the classification system.

The Putsche and Vertuch Classification.—The first published attempt at classification that has come to our attention is that by Putsche and Vertuch[8] in their monograph of the potato, in which they present a classification system (p. 10) which, though crude, indicates the desire, even in those early days, for some method by which the varieties could be grouped. This classification is based on the following parts of the plant: (1) plant (number and size of stems); (2) color of blossom; (3) method of propagation and source of stock; (4) shape and form of the tubers; (5) smoothness or roughness and thickness of the skin; (6) color of skin; (7) size of tubers; (8) character of the flesh; (9) taste of the flesh; (10) productiveness; (11) position of tubers in the soil; (12) period of maturity (early or late). The authors comment on their scheme of classification with reference to the first eleven divisions as follows:

> "It is scarcely necessary to observe that all these classifications are based upon variable quantities, which depend upon soil, position, climate and cultivation, and therefore are insufficient for a complete diagnosis. A less variable, more positive, and surer division is according to the ripening period."

Those ripening between the first and middle of July to the last of August were classed as earlies, while those ripening after the first of September were called late or main crop varieties.

The explanation given by the authors is a sufficient criticism of this scheme of classification to make further comment unnecessary, as it must be evident to all that it is an unworkable one.

Lenné's Classification.—The next classification system that has come to our attention is that worked out from varieties grown on the trial field of the Royal State Nursery near Potsdam, in Prussia, and reported by Director General Lenné.[6]

This classification is based on the color of the skin, the shape of the tuber and the color of the flesh. In this scheme fifteen combinations or groups were secured, *viz.*:

I. Yellow-skinned, rounded, yellow-fleshed varieties.
II. Yellow-skinned, rounded, white-fleshed varieties.
III. Yellow-skinned, elongated, yellow-fleshed varieties.
IV. Yellow-skinned, elongated, white-fleshed varieties.
V. Yellow-skinned, kidney-shaped, yellow-fleshed varieties.
VI. Yellow-skinned, kidney-shaped, white-fleshed varieties.
VII. Red-skinned, rounded, yellow-fleshed varieties.
VIII. Red-skinned, rounded, white-fleshed varieties.
IX. Red-skinned, elongated, yellow-fleshed varieties.
X. Red-skinned, elongated, white-fleshed varieties.
XI. Red-skinned, kidney-shaped, yellow-fleshed varieties.
XII. Red-skinned, kidney-shaped, white-fleshed varieties.
XIII. Blue-skinned, rounded, yellow-fleshed varieties.
XIV. Blue-skinned, rounded, white-fleshed varieties.
XV. Blackish-blue skinned, rounded, violet-fleshed varieties.

The number of varieties classified under each of these fifteen groups were as follows:

Group I.—71 varieties.
Group II.—22 varieties.
Group III.—12 varieties.
Group IV.— 3 varieties.
Group V.— 4 varieties.
Group VI.— 4 varieties.
Group VII.—11 varieties.
Group VIII.— 9 varieties.
Group IX.— 5 varieties.
Group X.—10 varieties.
Group XI.— 4 varieties.
Group XII.— 1 variety.
Group XIII.— 5 varieties.
Group XIV.— 9 varieties.
Group XV.— 2 varieties.

Vilmorin's Classification.—The third classification scheme, chronologically, is that of Vilmorin[11] who in 1882, and again in 1886 and 1902, published the results of many years' observations of a very complete collection of potato varieties. These varieties were grouped into 12 classes in 1886, and the 12 classes were further subdivided into 30 sections. In the 1902 edition only 9 classes were made; but these 9 classes were subdivided into 40 sections. Vilmorin's classification is considerably more elaborate than that of Lenné's previously given, the classes being based on the color and shape of the tubers, and that of the sections on the color, shape and size of the tubers, the depth of the eyes, the color of the sprouts in the dark, and the color of the flowers. The 9 classes are as follows:

1. Yellow, round.
2. Yellow, oblong.
3. Yellow, long.
4. Flesh-colored, oblong.
5. Rose or red, round.
6. Rose or red, oblong.
7. Rose or red, long.
8. Violet-colored.
9. Streaked (mottled).

The varieties included in class 1 are divided into ten sections, of which section 2 will serve as an illustration.

Section 2. Tubers, yellow or white, round; flowers colored, often abundant; flesh white; sprouts violet, more or less colored.

Kohler's Classification.—One of the first attempts at group classification in the United States is that of Kohler, who, in March, 1909, published the first results of his studies on the classification of potato varieties. In explanation of the classification of varieties Kohler[4] says:

"Varieties of potatoes may be classified into groups, artificially, by considering the tubers alone, and, naturally, by considering the entire plant. There is in many cases, and possibly all, a definite relation between type of tuber and type of plant, which means that the two methods of classification merge into each other....Varieties belonging to closely related groups often merge into each other and make it difficult to draw the line between the groups....The plan is to group together varieties having similar plants, and under these groups subdivide according to the shape of the tuber, and under tuber subdivide according to color, thus:

"I. Characteristics of vines.
A. Shape of tubers.
B. Color of tubers."

Kohler divided the varieties in the collection which he studied into eleven groups as follows:

I. Tuberosum.
II. Rural.
III. Endurance.
IV. Seedling B.
V. Green Mountain.
VI. Carman.
VII. Early Michigan.
VIII. Milwaukee.
IX. Russet.
X. Ohio.
XI. Early Market.

His plan of subdivision of the groups can be best illustrated by giving that of group I.

I. Tuberosum.
- A. Tubers roundish.
- B. Tubers somewhat elongated to about medium in length.
- C. Tubers long.

In a later publication,[4a] April, 1910, Kohler retained the same number of groups, but substituted new names for four of them. Some change was also made in the order in which they were listed as will be noted from a comparison of the two lists as presented below.

	List I.	*List II.*
I.	Tuberosum	Tuberosum.
II.	Rural	Wohltmann.
III.	Endurance	Rural.
IV.	Seedling B.	Endurance.
V.	Green Mountain	Factor.
VI.	Carman	Sharp's Express.
VII.	Early Michigan	Green Mountain.
VIII.	Milwaukee	Michigan.
IX.	Russet	Russet.
X.	Ohio	Ohio.
XI.	Early Market	Cobbler.

A careful review of Kohler's classification studies cannot fail to impress the reader with the extent of the work performed; and, if one keeps in mind the fact that he was blazing a new trail, as it were, so far as an American classification was concerned, we must concede that a very fair beginning was made.

His work has been a source of help to those who followed him.

Ballou's Classification.—Ballou's classification,[1] which appeared about the same time as Kohler's second one, describes seven groups. The author explains that in this classification he has reduced the groups to the least possible number, 7, and that only a few of the many varieties that might easily be included in each of the groups are mentioned.

He further states that the classification is based principally upon the similarity of the character of the tubers of the different varieties, without special consideration of the similarity of the plants of each; but that in many cases, however, there is a similarity of plants as well as tubers. The seven groups in Ballou's classification are:

Triumph.	Green Mountain.
Early Market.	Seneca Beauty.
Early Ohio.	Rural New Yorker.
Early Rose.	

Milward's Classification.—In 1912, Milward[7] classified the commercial potato varieties of Wisconsin into three groups which were considered to represent distinctive types. These were called the round white, the long white, and the rose groups of potatoes. The first two groups are classified as follows:

Group 1. *Round white.*—

Tubers: Round to oval and slightly flattened. Surface generally netted. Skin white, and flesh white.

Flowers: White or purple.

Group 2. *Long white.*—

Tubers: Long oblong in shape and sometimes flattened. Skin and flesh white.

Fitch's Classification.—Two years later Fitch[2a] described seven groups of American varieties of potatoes, *viz.,* the Rural, Early Ohio, Irish Cobbler, Green Mountain, Burbank, Peerless or Pearl, and Bliss Triumph. The description of each of these groups is good, and is well worth the careful study of those interested in the characteristic appearance of the members of each of them. Photographs representing the range of variation in tuber shape within each group enable the student to acquire a fairly good conception of the range of variation in the form of the tubers.

Kranz's Flower-stalk Classification.—Kranz[8] has recently suggested another character for potato identification, *viz.,* the position of the flower stalk. He found that in the Irish Cobbler, Early Rose, and Early Ohio the flower stalks are borne in the axil formed by a leaf and the main stalk. The Triumph, Burbank and Green Mountain bear their flower stalks on the petiole of the leaf. In the Rural group the flower stalks are borne on the main stem, usually at a slight distance from the axil of the leaf.

Snell's Classification.—This classification, published in 1921,[9] is based on date of ripening, color of tubers, and plant, stem, leaf and flower characters. The main classification, however, is based on the first two characters. The author divides German potato varieties into two classes or sections:

I. Early or medium early.

II. Late or medium late.

Four groups of potatoes are assigned to the first division, while the late or medium late varieties are subdivided into two sections: (a) those with white or blue tubers, and (b) those with red tubers. The first subdivision includes three groups and the second two.

The description of the tubers in each of these groups is greatly facilitated by a colored plate. The flower and sprout characters are shown on plate 2.

Stuart's Classification.—In March, 1915, Stuart[10] published a system of classification somewhat similar to that of Fitch's, although the latter's bulletin did not come to his attention until page proof of bulletin 176 was being corrected, when a footnote was inserted, mentioning the Iowa publication. In this classification eleven groups are recognized. These were based on studies extending over a period of ten years, in which the author had an opportunity to study the behavior of varieties from Maine to California and from New Jersey to Florida. In discussing his proposed system of classification he says (p. 3):

"In presenting the following classification key and group description, no one realizes more clearly than does the writer that there is still much to be desired. It is hoped, however, that this classification will serve as a starting point upon which to base further studies. It is quite probable that the groups here presented will, in many cases, resolve themselves into one or more sub-groups or sections which are based on finer distinctions than those given for the group as a whole. It is equally certain that some new groups will have to be made in order to include those varieties which do not, at present, seem to fit into any of the classes now proposed."

"The value of studying varietal groups cannot be too strongly emphasized. When the varieties fitting into such groups are planted in adjacent rows the comparative differences, as well as similarities, are more easily noted. The recognition of old varieties under new names is almost certain to result from such a study, and should tend to discourage the present practice of some of the seedsmen who manufacture new varieties out of old ones."

The following classification key has been found very helpful in studying potato varieties. It is not an exact reproduction of bulletin 176, some minor changes having been thought desirable. In all other respects the two keys are identical.

Classification Key (Stuart's)

(The color values are based upon the chart published by the French Chrysanthemum Society, Paris, 1905).

Group 1. *Cobbler.*—

Tubers: Roundish to roundish-flattened or slightly oblong, stem-end usually deeply recessed or notched; skin creamy-white. (Plate I-A).

Sprouts: Base, leaf scales and tips slightly or distinctly tinged with reddish-violet or magenta. In some cases the color is nearly, if not entirely, absent. (Plate I-A).

Flowers: Light rose-purple, under intense heat may be almost white. Plants flower very profusely in some sections. (Plate I-A').

Group 2. *Triumph.*—

Tubers: Roundish to roundish-flattened; skin solid red or magenta in the case of the Triumph to creamy-white with more or less numerous splashes of red or carmine in the case of Noroton Beauty; and white with faint to pronounced coloring in the eyes in the case of White Triumph; maturing early. (Plate I-B).

Sprouts: Base, leaf scales and tips more or less deeply suffused with reddish-violet. (Plate I-B).

PLATE I.

A—Tuber of the Irish Cobbler showing color of skin and of sprout.

A′—Flower truss of the Irish Cobbler showing size and color of buds and expanded blossoms.

B—Tuber of the Triumph variety showing typical appearance of the skin and sprouts.

B′—A typical flower cluster of the Triumph showing paucity of individual flowers and evidences of premature dehiscence, or dropping off of bloom.

C—A typical tuber of the Pearl variety. Note deep stem-end recession and heavy shouldering of tuber.

C′—A flower truss of the Pearl. True-to-type Pearls seldom show more than two to three expanded flowers in any one cluster and always present evidence of the premature dropping of flower buds before opening.

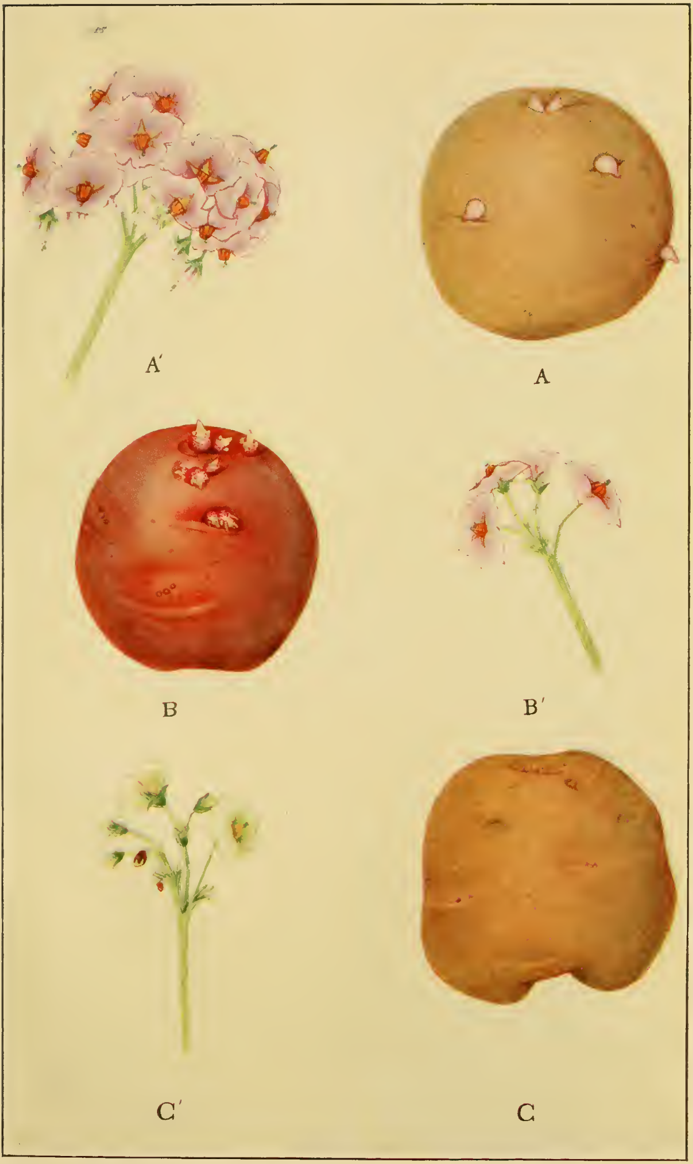

A′
A
B
B′
C′
C

PLATE II.

D—A representative Early Rose tuber showing skin and sprout characters.

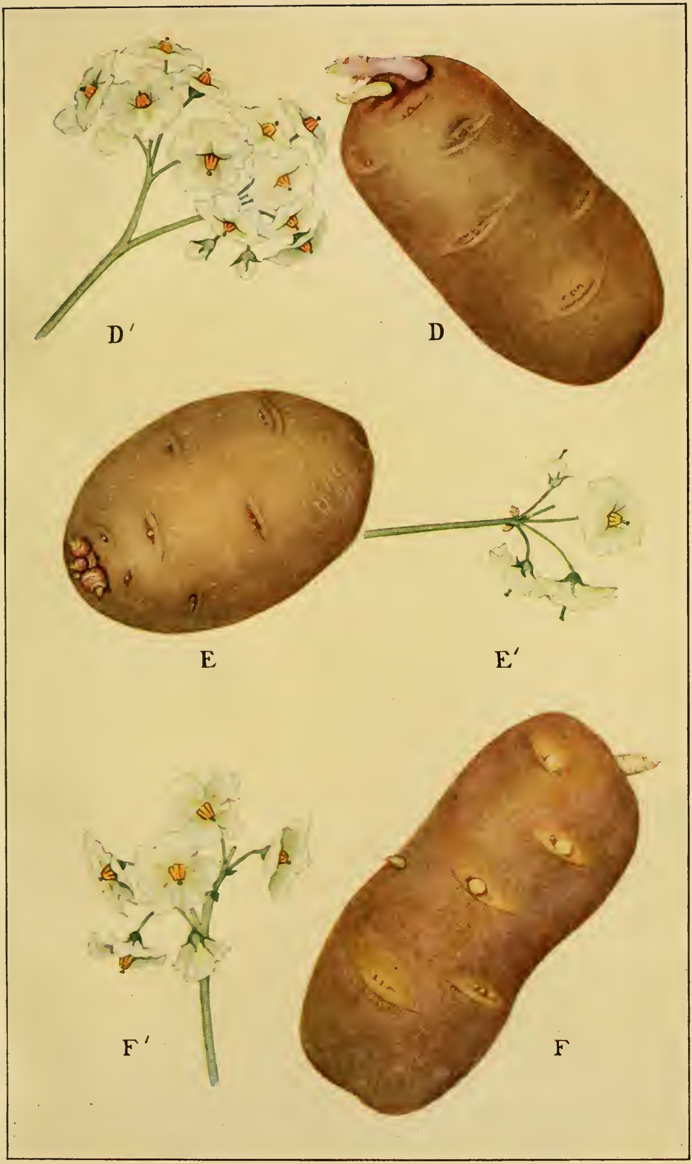
D′—An average flower truss of the Early Rose. Note profusion of bloom.

E—A well shaped Early Ohio tuber showing characteristic skin and sprout coloration.

E′—An average flower truss of the Early Ohio. Note paucity of bloom and light color of stamens.

F—A desirably shaped Beauty of Hebron tuber. Note unevenness of skin coloration and creamy white appearance of skin surrounding the eyes.

F′—A flower truss of the Beauty of Hebron. Note intermediate stage between Early Rose and Early Ohio in number of blooms.


D′
D
E
E′
F′
F

Flowers: Very light rose-purple, rather small, flowers sparingly. (Plate I-B′).

Group 3. *Early Michigan.*—

Tubers: Oblong or elongate-flattened; skin white or creamy-white, occasionally suffused with pink around bud-eye cluster in Early Albino.

Sprouts: Base light rose-purple; tips creamy-white or light rose-purple.

Flowers: White, rather profuse.

Group 4. *Rose.*—

Tubers: Elongate-flattened to spindle-shaped flattened in section 1, or oblong-flattened in the case of section 2; skin flesh-colored or pink; bud-eye cluster deep magenta, (Plate II-D); in the case of the White Rose the skin is white.

Sprouts: Base and internodes creamy-white to deep rose-lilac; leaf scales and tips cream to rose-lilac. (Plate II-D).

Flowers: White; blooms fairly abundant. (Plate II-D′).

Group 5. *Early Ohio.*—

Tubers: Round-oblong, or ovoid, generally slightly flattened though not always; skin flesh-colored or light pink, usually with numerous medium-sized, rather conspicuous russet dots or lenticels. (Plate II-E).

Sprouts: Base, leaf scales and tips more or less deeply suffused with carmine-lilac, to violet-lilac or magenta. (Plate II-E).

Flowers: White; moderate bloomer. (Plate II-E′).

Group 6. *Hebron.*—

Tubers: Elongated, and distinctly flattened, sometimes spindle-shaped; skin creamy-white, more or less colored with flesh color, or light pink. Creamy-yellow around eyes. (Plate II-F).

Sprouts: Base creamy-white to light lilac; leaf scales and tips pure mauve to magenta, color often absent. (Plate II-F).

Flowers: White; moderately free bloomer. (Plate II-F′).

Group 7. *Burbank.*—

Tubers: Long, cylindrical to distinctly flattened, inclined to be somewhat spindle-shaped; skin white to creamy-white (Plate III-G), smooth and glistening or slightly netted, or deeply netted and dark, russet in the case of section 2. (Plate III-G′).

Sprouts: Base creamy-white or faintly tinged with magenta; leaf scales and tips usually lightly tinged with magenta but quite often color is absent. (Plate III-G and G′).

Flowers: White, moderate bloomer. (Plate III-G″).

Group 8. *Green Mountain.*—

Tubers: Moderately to distinctly oblong, usually broad, flattened with blunt ends; skin a dull creamy or light russet color; sometimes rather heavily netted especially toward the seed end. (Plate III-H).

Sprouts: Section 1.—base, leaf scales and tips creamy-white. (Plate III-H); section 2.—base usually white, occasionally tinged with magenta; leaf scales and tips tinged with lilac to magenta; usually color is very faint.

Flowers: White; blooms profusely. (Plate III-H′).

Group 9. *Rural.*—

Tubers: Broadly round-flattened to short oblong, or distinctly oblong-flattened; skin creamy-white, usually smooth, but sometimes lightly netted; or heavily netted, and russet color as in section 2. (Plate III-I and I′).

Sprouts: Base dull white; leaf scales and tips violet-purple to pansy-violet. (Plate III-I).

Flowers: Central portion of corolla deep violet-purple with the color growing lighter toward the outer portion; five points of corolla white or nearly so. Moderate bloomer. (Plate III-I″).

Group 10. *Pearl.*—

Tubers: Round-flattened to heart-shape flattened, usually heavily shouldered due to deep recession of stem; skin dull white or buff in section 1, (Plate I-C), distinctly russet or brownish color in section 2, or a deep bluish-purple with occasional creamy-white splashes, usually around the eyes in section 3.

Sprouts: Sections 1 and 2.—base, leaf scales and tips usually faintly tinged with lilac, (Plate I-C); section 3.—base, leaf scales and tips vinous-mauve.

Flowers: White; blooms very sparingly. (Plate I-C′).

Group 11. *Peachblow.*—

Tubers: Round to round-flattened or round-oblong; skin creamy-white, splashed with crimson or solid pink; eyes bright carmine. Includes some early-maturing varieties. (Plate IV-J,J′ and K).

Sprouts: Base, leaf scales and tips more or less suffused with reddish-violet. (Plate IV-J and K).

Flowers: Purple, usually rather free bloomers. (Plate IV-J″ and K′).

Group 12. *Up-to-Date.*—

Tubers: Oblong-flattened to somewhat obovate-flattened; skin creamy-white, moderately netted or nearly smooth. (Plate IV-L).

Sprouts: Base dull white, leaf scales faintly to distinctly tinged with light magenta. (Plate IV-L).

Flowers: Rose-purple; moderate to fairly profuse bloomer. (Plate IV-L′).

Pistil: Usually short, thick and curved with enlarged stigma.

The last group (12) has been added to accommodate a few varieties of Scotch-English origin which are being grown to some extent in the United States and to a greater degree in Canada, and from which there seems to be springing up, or emanating, certain varieties presumably of American origin which have been more or less widely disseminated. Whether these varieties are simply the Up-to-Date or Factor re-named is difficult to determine, but in any event they must be considered members of a group which, in certain sections of the New World, may become the leading commercial type of potatoes grown.

In regard to the naming and describing of the groups the bulletin says (*l.c.* p. 5):

"In deciding upon the name by which each group shall be known, an attempt has been made to select that of the variety which seems most nearly to represent the group as a whole and which, at the same time, is most widely known."

The classification key presented is too brief to do other than to serve as a simple means of placing a variety in the group to which it seems related. The more complete description, which follows, is in a large measure a reproduction of that published by

PLATE III.

G—A well shaped tuber of the Burbank variety showing skin and sprout coloration.

G′—A fair specimen tuber of the Russet Burbank. Note deep russet color and heavy netting of skin.

G″—Flower truss of the Burbank potato. Note length ot petals of unopened buds and light color of stamens.

H—A good specimen tuber of the Green Mountain variety.

H′—A small flower truss of the Green Mountain potato. Note deep orange-yellow color of stamens. Compare shape of unopened buds with those of the Burbank.

I—A show tuber of the Rural New Yorker No. 2 (Rural Group). Note shallow eyes and violet color of tips of sprouts and leaf scales.

I′—A good specimen of the Russet Rural potato.

I″—A typical flower truss of the Rural Group of potatoes. Note color of petals of unopened buds and of corolla of expanded flower.

I‴—A portion of the stem of a Rural New Yorker No. 2 plant showing coloration of the epidermis.

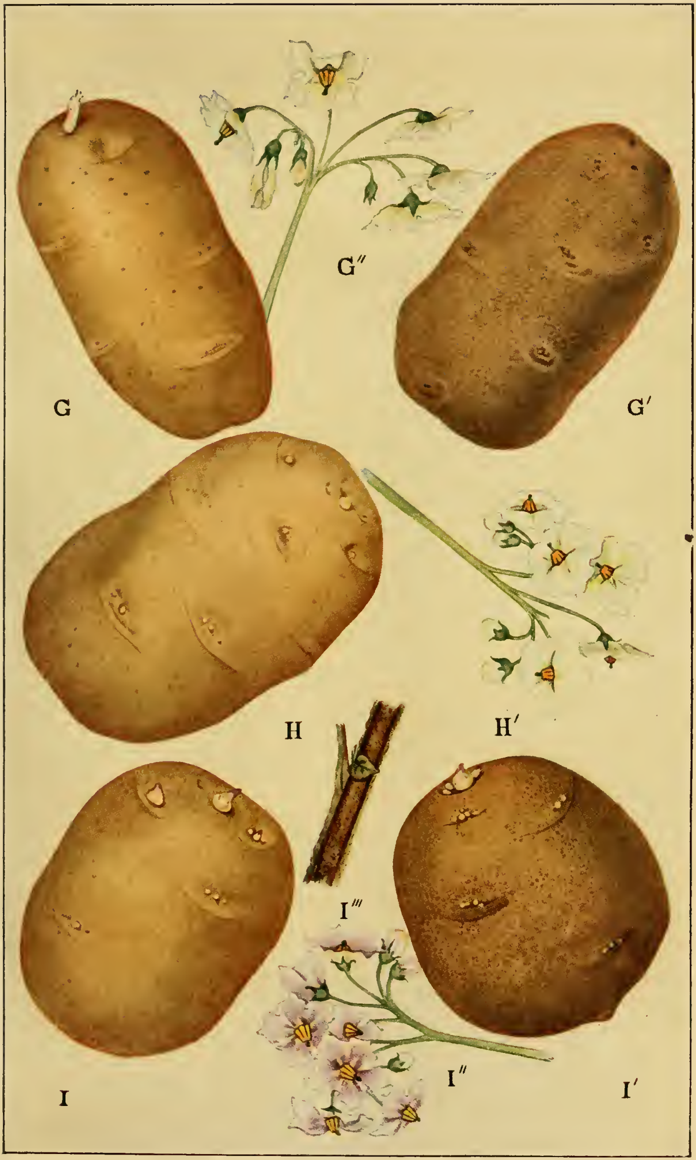

G
G′
G″
H
H′
I
I′
I″
I‴

PLATE IV.

J—A McCormick tuber somewhat better than the average shape, showing normal skin and sprout coloration.

J′—A fair tuber specimen of the White McCormick. Note absence of color in skin and sprouts.

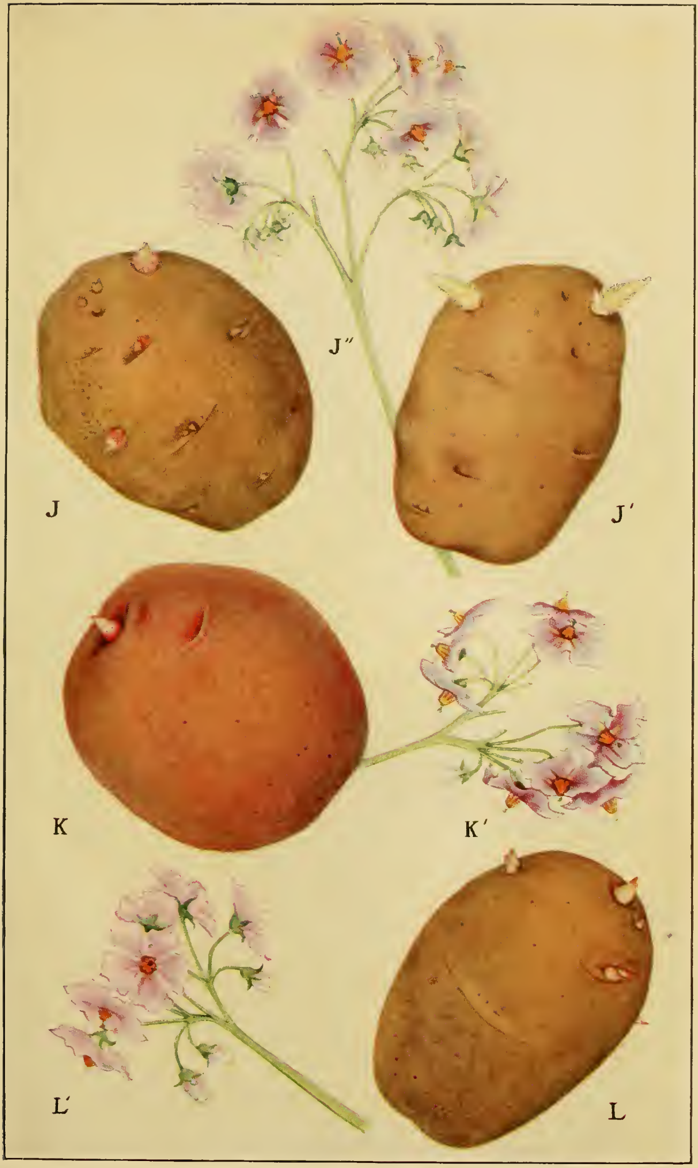
J″—An average-sized flower truss of the McCormick variety.

K—A good specimen tuber of the Perfect Peachblow (Red McClure) variety.

K′—Flower truss of the Perfect Peachblow.

L—A representative tuber of the Up-to-Date variety of potato. Note shallowness of eyes and coloration of sprouts.

L′—Flower truss of the Up-to-Date variety. Note similarity of color of unopened buds to that of the McCormick.


J″
J
J′
K
K′
L′
L

Stuart (*l.c.* p. 5). Such changes as occur are the result of a more intimate knowledge of the group as a whole and the type variety in particular.

Description of Groups. Group 1.—The Cobbler group represents a class of early-maturing potatoes. The Irish Cobbler

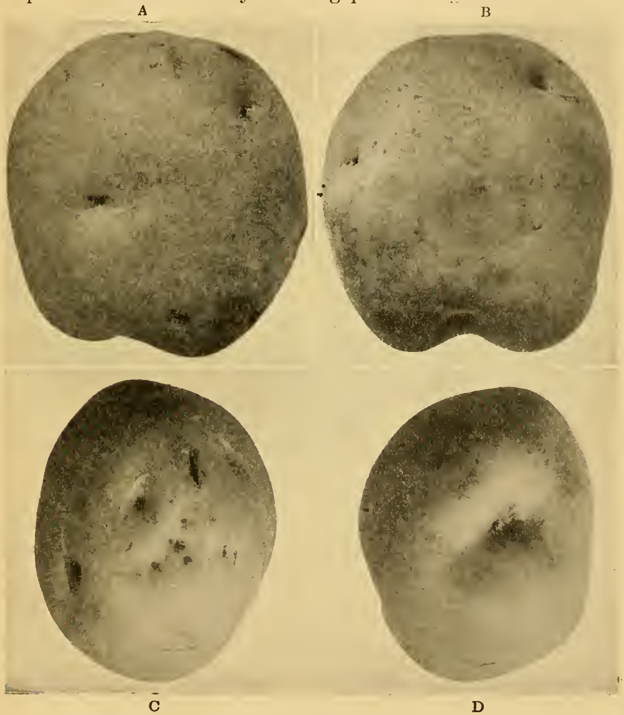


Fig. 237.—Four views of a well-shaped though rather shallow-eyed Irish Cobbler tuber. A—upper: B—lower; C—seed end; D—stem end view.

is by far the most extensively grown variety of this group. It is now, and has been for a number of years past, the leading commercial early market variety in the Atlantic Coastal Plain region from Long Island to Georgia. It is also grown extensively in the

Louisville, Kentucky, district. Large quantities of Irish Cobbler are also grown in some of the late or main-crop producing sections of the North, notably of northern Maine and New York and in certain localities in Michigan, Wisconsin and Minnesota. In the northern sections it is principally grown for the purpose of supplying seed to the southern truck grower. Figures 237 and 238, and Pl. 1-A illustrate different types of potatoes belonging to group 1.

Description.—Matures early. Vines medium to above medium in size with somewhat spreading habit of growth. Stems dark green, stocky and rather short-jointed. Leaves large, flat or nearly

Fig. 238.—Two representative Irish Cobbler tubers showing average depth of bud eyes.

so, more or less flaccid in northern Maine when grown under optimum conditions, but much smaller, as a rule, in the Central West; they are medium dark green in color. Flowers numerous, rather large, light purple- or rose-lilac; under intense heat the color may be practically unexpressed. Tubers roundish to roundish-flattened or slightly oblong-flattened, the stem-end usually rather deeply notched giving a rather shouldered appearance to the base of the tuber (Pl. 1-B). Eyes medium in number, varying from shallow to rather deep, particularly in the bud-eye cluster, (Pl. II). Skin usually smooth, but sometimes fairly well netted, as in the case of the Potentate, light creamy-white in color. Sprouts stout and rather stubby, vary in color at the base from a very faint reddish-violet or magenta to a perceptible coloration; the tips and leaf scales are usually tinged with the same color. Occasionally the color is almost, if not entirely, absent.

The following varieties have been classed in the Cobbler group and, to all intents and purposes, most of them are identical.

Early Beauty.	First Early.
Early Dixie.	Flourball.
Early Eureka.	Happy Medium.
Early Petoskey.	Irish Cobbler.
Early Standard.	Irish Daisy.
Early Victor.	New White Victor.*
Early Waubonsie *	Potentate.
Extra Early Eureka.	Trust Buster.*

Group 2. Triumph.—This group includes the earliest named varieties grown in the United States. The Triumph is the leading commercial variety of the group, as well as its oldest member. It

Fig. 239.—A well-shaped and good type Triumph tuber natural size.

is chiefly grown in the States of Florida (southern part), Alabama, Mississippi, Louisiana, Texas, Oklahoma, Arkansas and portions of Tennessee, in which sections it is the leading truck crop variety. In the North, it is grown most extensively in Maine, Wisconsin, Minnesota and Nebraska, in order to supply the southern grower with seed stock. Ordinarily it is not grown in the North primarily for table stock.

Description.—Very early. Vines medium to small, fairly compact, not much branched. Stems short, stocky, dark green.

* Classified by Prof. A. L. Dacy, Exp. Station, Morgantown, W. Va.

FIG. 240.—Three good specimen tubers of the Triumph variety showing some variation in depth of eyes.

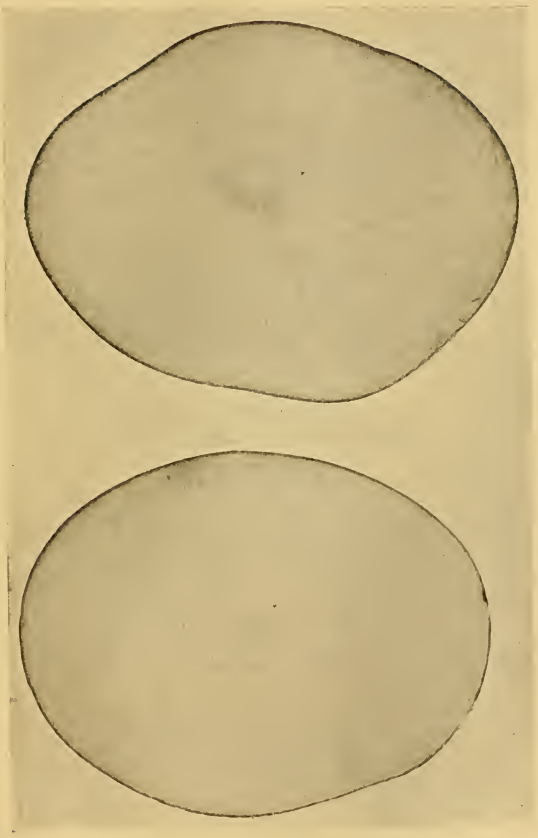


FIG. 241.—Cross section of a Triumph potato. Natural size.

Flowers usually few in number, small in size, and of a rose-lilac color. Tubers roundish to roundish-flattened with stem-end slightly to distinctly shouldered (Figs. 239 to 241 and Pl. I-B). Eyes medium in number, rather shallow; bud-eye cluster generally more or less depressed. Skin creamy-white, generally with pink eyes, and occasionally with splashes.—White Triumph.—with few or many splashes of crimson as in the Quick Lunch and Noroton Beauty; or solid red, or occasionally solid red splashed with crimson, as in the Triumph. Flesh a creamy-white. Sprouts have base, leaf scales and tips more or less deeply suffused with reddish-violet.

The varieties assigned to the Early Michigan group are as follows:

Early Prospect.	Quick Lunch.
Honeoye Rose.	Triumph (Bliss's).
Noroton Beauty.	White Triumph.
	Wood's Earliest.

Of the above list of names Early Prospect is perhaps the most flagrant example of a recent occurrence of the re-naming of an old and easily recognized standard commercial variety, as it is a simon-pure Triumph. Honeoye Rose, Noroton Beauty, Quick Lunch and Wood's Earliest are identical. The varieties of this group seem to be peculiarly susceptible to the mosaic disease.

Group 3.—The Early Michigan group has been provided for the purpose of accommodating certain early-maturing white-skinned varieties which, owing to the character of their vine growth, color of flowers, and color and shape of tubers do not fit into either of the two preceding groups or of any of the succeeding ones. The members of this group are most closely related to the Green Mountain class of potatoes. Commercially speaking, they are not very extensively grown but apparently have a place in certain localities in the Middle West as, for example, around Chicago and Detroit.

Description.—Medium early to mid-season. Vines of medium size. Flowers fairly abundant, medium size, white. Tubers oblong-flattened to elongate-flattened or ovoid (Figs. 242 and 243). Eyes numerous, medium size and depth. Skin white or creamy-white or, in the case of the Early Albino, occasionally suffused with pink around the bud-eye cluster. Sprouts light rose-purple at the base, with the scales and tips creamy-white or tinged with light rose-purple.

The varieties assigned to the Early Michigan group are as follows:

Dew Drop.	Early Puritan.
Early Albino.	Ehnola.
Early Harvest.	Extra Early Sunlight.
Early Michigan.	

FIG. 242.—A good specimen of Early Michigan potato, Group 3.

FIG. 243.—Three average specimen tubers of the Early Michigan Group.

Group 4. Rose.—In point of numbers, the Rose group is one of the largest. With the exception of the Extra Early White Rose, all of the varieties in this group have pink or flesh-colored tubers and all, save the late Rose, may be classed as early or mid-season varieties. The Early Rose is perhaps more widely grown than any other variety, outside possibly of the Early Ohio; but neither it nor the group as a whole can be regarded as an important commercial factor in the potato industry of this country, because in

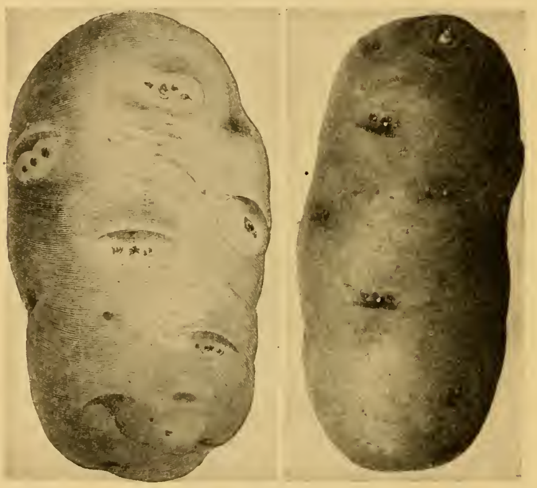


Fig. 244.—Tuber on left reproduced from one of the original cuts used to illustrate the Early Rose variety, Group 4. Note prominence of the eyes. Right from the photograph.

no locality except Florida are they extensively grown at the present time. However, the group is an interesting one, as the Early Rose, in a sense, represents the fountain-head, as it were, of many of our present day varieties belonging to other groups.

In order to include certain varieties, which apparently belong to this group, but which differ somewhat in growth of plant, shape of tuber, and color of skin and sprouts, it has been found necessary to make two sections, to the first of which are assigned the true Early Rose types. In this connection it is desired to call attention to the fact that in Department Bulletin 176, previously referred to, a third section was provided in this group, in order to include certain varieties which possess some of the Early Rose attributes, but which differed in color of bloom, and shape and color of tuber to such an extent that it has been decided to omit them entirely in the present classification. The comparative unimportance of the varieties, from a commercial standpoint, is also another consideration in leaving them out.

In the description that follows, an attempt is made to cover the Early Rose proper, and to note such departures from it as may occur in varieties belonging to section 2.

Fig. 245.—A well-shaped Early Rose tuber, but it is not typical of the variety.

Description.—Section 1. Vines of medium height, with stout, rather erect, dark green stems and medium to large leaves. Flowers rather abundant, white. Tubers elongate-flattened to spindle-shape flattened (Figs. 244 and 245, and Pl. II-D). Eyes numerous and well distributed, shallow to medium in depth, sometimes protuberant (Fig. 244). Skin smooth and, except in the White Rose, of a rather deeper shade of flesh color than Early Ohio; the seed end usually a deep pink. In some types of soil, and in some regions, the color of the skin is very much intensified. Flesh creamy-white, sometimes streaked with red or pink. Sprouts rather long, medium thick, the base not much enlarged and usually clearly tinted with rose-lilac; leaf scales and tips creamy-white or tinged with rose lilac (Plate 2-D).

The following varieties have been classed in section 1:

Clark's No. 1.	Extra Early Fillbasket.
Early Durham.	Extra Early Vermont.
Early Fortune.	Houlton Rose.
Early Maine.	Late Rose.
Early Rose.	Northern Beauty.
Early Sunrise.	Rochester Rose.
Early Thoroughbred.	Somer's Extra Early.
Early Vermont.	Thorburn.
Early Walters.	White Rose (Extra Early and Woodbury's).

Section 2.—Vines larger and more luxuriant than those of section 1. Flowers rather abundant, but not opening as freely as in section 1. Tubers broad-roundish flattened to oblong-flattened, with rather blunt ends in the case of the King. Eyes not so numerous as in section 1; medium, shallow except in overgrown

FIG. 246.—A good specimen of a spaulding No. 4 tuber grown at Hastings Florida.

specimens. Skin slightly deeper colored than that of the Early Rose. Sprouts shorter and thicker and usually enlarged at the base; color of sprouts mauve; leaf scales and tips deep mauve or magenta.

The varieties classed under section 2 are:

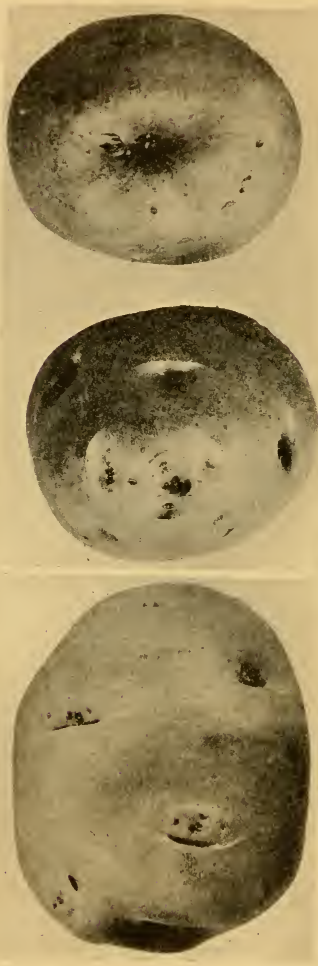
King.
Manistee (Early and Improved).
Spaulding No 4. (Rose 4).

Group 5. Early Ohio.—In many respects the members of the Early Ohio group are very similar to those of the Rose, but inasmuch as it is so well known, and is so extensively grown commercially, it seems desirable to retain the Early Ohio varieties in a distinct group, rather than to merge them with the Rose varieties. The Early Ohio varieties, with the exception of the Late Ohio,

FIGS. 247. AND 248.—A good specimen of Early Ohio as produced in Maine. Note shortened longitudinal axis and increased transverse diameter.

FIG. 249.—An excellent specimen of Early Ohio from the Middle West. Note lengthened axis and decreased diameter.

are somewhat earlier-maturing than those of the Rose, and are much less profuse bloomers. This is made all the more apparent by the failure of a large number of the flower buds to fully expand. In the potato-growing regions of the Middle West, it is still one of



A B C

Fig. 250.—Three views of Early Ohio tubers, A upper surface, B apical or bud-eye end, C basal or stem end.

the leading commercial varieties. This is particularly true in the Red River Valley of Minnesota and North Dakota, and in the Kaw Valley in Kansas; it applies equally as well to other less well-known localities.

Description.—Vines quite similar to those of the Early Rose, though as a rule they are somewhat stockier, do not branch as

Fig. 251.—A large but well-shaped and true-to-type, Early Ohio from Montana. Natural size.

freely, and mature a week to ten days earlier. Flowers are white, but not quite so large as in the preceding group; the anthers are also considerably lighter in color, being a lemon-yellow instead of a bright orange-yellow. Tubers are ovoid to round-oblong or cylindrical, with rounded seed and stem-ends in well-grown specimens (Figs. 247 to 251, Pl. II-E). Eyes numerous, rather shallow but strong, sometimes protuberant. Skin flesh or light pink, except in the case of the White Ohio, which has a creamy-white skin with pink eyes; the seed end is usually a deeper shade of pink; surface of the skin more or less numerously dotted with small,

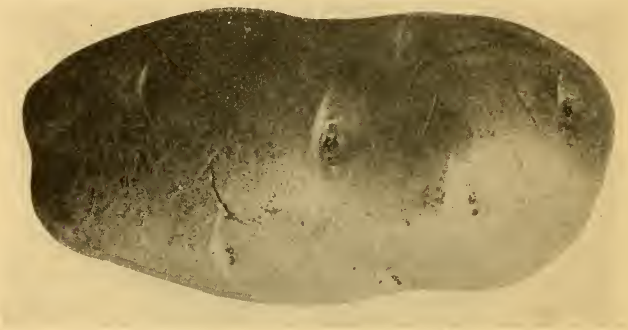


FIG. 252.—A good specimen of Beauty of Hebron.

raised, corky dots (lenticels); more conspicuous when grown in some soils than in others. Sprouts short, much enlarged at the base, color varying from carmine-violet to violet-lilac or magenta-lilac.

The following varieties have been placed in the Early Ohio group:

Early Acme.	Late Ohio.
Early Market.	Majestic (New Majestic).
Early Ohio.	Prize Early Dakota.
Early Six Weeks.	Ratekin's Red River Special.
	White Ohio.

Of the above list the Early Market, Majestic, Prize Early Dakota, and Ratekin's Red River Special are simply Early Ohio re-named.

Group 6. Hebron.—The varieties in the Hebron group are chiefly distinguished from those of the Rose group by the color of their tubers. Most members of the group are early or mid-season varieties, the only exception noted being the Late Beauty of Hebron. Thirty-five years or more ago the group had some commercial importance, as both the Early and the Late Beauty of Hebron were rather extensively grown. Their decadence has been largely due to the fact that they are very susceptible to the late blight, and they have more or less degenerated or "run-out." Another and perhaps more important reason is that they have been superseded by better varieties. At the present time they are not grown commercially in any section, with the possible exception of certain localities where they are grown, to a limited extent, for the general seed trade.

Description.—Varieties of this group may, with one exception, be classed as second early or mid-season. The Late Beauty of

Fig. 253.—Reproduced from original cut of Burbank's Seedling. Note prominent eyes. Group 7, section 1.

Hebron matures about the same time as the Green Mountain. Vines very similar to the Early Rose. Flowers white. Tubers elongated and distinctly flattened, sometimes spindle-shaped; ends more or less blunt (Fig. 252, Pl. II-F). Eyes numerous, medium deep. Skin creamy-white, more or less clouded with flesh color or light pink. Sprouts very similar to those in section 1 of the Early Rose group, but with rather less color.

The varieties classed in this group are as follows:

Beauty of Hebron (Early B. of H.).
Beauty of Hebron (Improved B. of H.).
Beauty of Hebron (Late B. of H.).
Columbus.
Country Gentleman.
Crown Jewel.
Early Bovee.
Gem of Aroostook.
Harbinger.
Junior Pride.
Milwaukee.
New Queen.
Quick Crop.
Star-of-the-East.
Vigorosa.
White Elephant.
White Hebron.

Group 7. Burbank.—In the early period of its introduction the Burbank potato or Burbank's Seedling, as it was then known, was rather extensively grown in the northeastern part of the United States; but for the past quarter of a century, its popularity as a commercial variety has waned to such an extent that it is now rarely grown except for seed purposes. In the West, on the other hand, it is still quite popular in many sections. The russet type of the Burbank is a more recent acquisition, and is generally considered superior to the original Burbank in table quality. The smooth skin or true Burbank type is grown rather extensively in the Stockton district in California, and in the western part of Oregon; while the russet types are produced in the Yakima Valley in Washington, and rather generally in Idaho and in certain parts of Nevada, Utah, Colorado and western Nebraska. The russet members of this group are assigned to section 2.

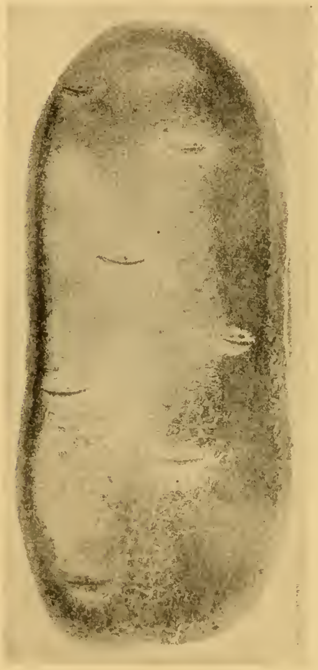


FIG. 254.—Reproduced from original cut of the White Star variety. This variety was considered as a straight Burbank by several of the past generation of potato breeders.

Description.—Vines bushy and medium large. Stems light to medium green, branched and spreading. Leaves abundant and medium in size, usually the major leaflets are rather long and narrow, tapering to a point which is generally curved, medium green in color. Flowers not very abundant, many falling off before opening; pedicel of flower cyme generally rather long and erect, and usually standing well above the foliage; calyx lobes rather long, usually extending well beyond the corolla before flower opens. There are no distinguishable differences in the vine growth or floral characters of the smooth and russet-skinned types of the Burbank.

Section 1.—Tubers long, cylindrical to distinctly flattened in

Fig. 255.—Three fairly good specimens of eastern grown Burbank tubers.

Fig. 256.—Three good typical Wisconsin-grown, Russet Burbank tubers. Note moderate netting of skin.

shape, inclined to be somewhat spindle-shaped; skin white to creamy-white, smooth or slightly netted (Figs. 253-255, Pl. III-G).

Sprouts, base creamy-white, or faintly tinged with magenta; leaf scales and tips usually lightly tinged with magenta.

Section 2.—Tubers have russet skin, heavily netted or reticulated (Figs. 256 and 257, Pl. III-G′). In all other respects than color and netting of the skin, the tuber characters of the Russet Burbank are similar to those of Section 1.

A B

FIG. 257.—Tuber "A" represents an ideal-shaped Russet Burbank. Tuber "B" represents a broader, flatter shape which is not considered desirable for seed stock. Tubers are typical in netting of most western-grown stock such as may be found in Colorado, Idaho and other western states.

The varieties given below are considered members of this group:

Section 1. Burbank or Burbank's Seedling.
Late Puritan.
Money Maker.
Pride of Multnomah.
White Beauty.
White Chief.

Section 2. California Russet.
Cambridge Russet.
Golden Russet (Old's).
Netted Gem.
New Wonderful.
Russet Burbank.
Rusty Coat.
Scabproof (Salzer's).

Group 8. Green Mountain.—The members of the Green Mountain group may be said to divide honors with those of the Rural in their commercial importance as a late or main-crop variety. They seem to be peculiarly well adapted to northern latitudes,

FIG. 258.—Three good specimens of Wisconsin-grown Green Mountain tubers.

FIG. 259.—A good type specimen of Green Mountain.

where the rainfall is abundant and the temperature is not excessively high. As a rule they do not succeed as well in localities where they are subjected to unfavorable conditions of growth during the time they are forming tubers, as do the members of the Rural group. Recent observations indicate that most, if not all, of the members of this group are peculiarly susceptible to mosaic infection of the foliage with a consequent material reduction in the yield of the tubers. They are also among the most susceptible to late blight infection of both vine and tuber.

The varieties in this group are divided into two sections, according to whether they have white or slightly-colored sprouts.

Description.—Vines large, strong and well-branched. Stems light green in color, usually distinctly winged. Leaves large, leaf-

Fig. 260.—Cross section of a Green Mountain tuber. Natural size.

lets broad, smooth and more or less flaccid, medium green. Flowers abundant, white, fair size, rarely producing seed balls naturally, except under very favorable climatic conditions. Tubers moderately to distinctly oblong, usually broad-flattened with more or less blunt ends (Figs. 258-260, Pl. III-H); eyes medium in number, rather shallow, with strong bud-eye cluster. Skin a dull creamy-white or light russet color when well netted. Sprouts in section 1 rather short and stubby, base, leaf scales and tips creamy-white, while in section 2, with the exception of Twentieth Century, they are mostly without color at the base; the leaf scales and tips are usually faintly or distinctly tinged with lilac or magenta.

The following varieties have been classed in the white sprout division:

Section 1.

Bethel Beauty.
Bishop's Pride.
Blightless Wonder.
Bugless (Gurney's Bugless).
Clyde.
Delaware.
Farmer.
Freeman.
Gold Coin.
Green Mountain.
Green Mountain Jr.
Green Mountain (Lowell's).
Hasting's (2).
Keystone.
Late Blightless.
Long Island Wonder.
McGregor.
McKinley Mill's Pride.
New Oregon.
Norcross.
Pride.
Silver King (2).
Snow.
Uncle Sam.
Washington.†
White Harvest (Gurney's).
White Mountain.

Section 2.

American Giant.
Carman No. 1.
Empire State.
Longfellow.
Rustproof.
State of Maine.

Group 9.—The Rural group includes a large number of strong-growing, late-maturing varieties. Collectively they are now com-

Fig. 261.—Upper and lower view of a Rural New Yorker No. 2 tuber.

monly referred to by New York State growers as "blue-sprout" potatoes, in contradistinction from the "white-sprout" varieties belonging to the Green Mountain group. The members of the Rural group seem to be admirably adapted to southern and western

† Classified by A. L. Dacy, Exp. Sta., Morgantown, W. Va.

New York, and to certain sections of Michigan, Wisconsin, Iowa, and Minnesota. The tubers keep well in storage and are slow to germinate in the Spring. The vines develop slowly at first, but, as the season advances, they branch rather freely and develop fairly

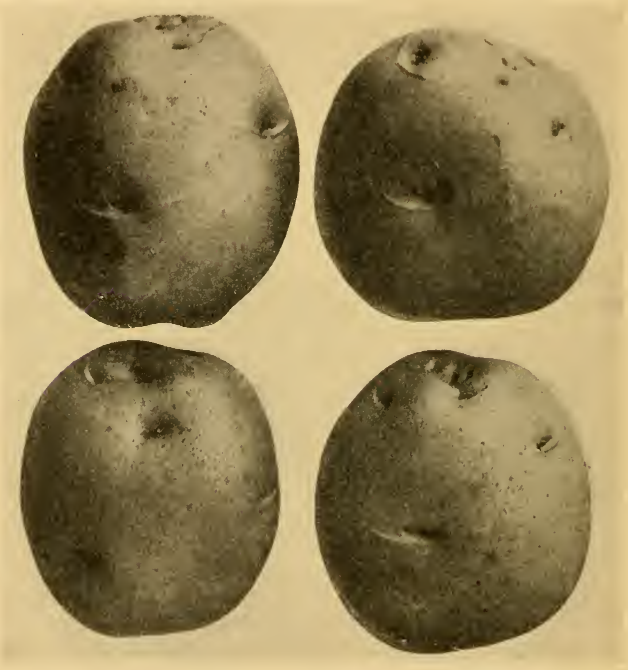


FIG. 262.—Four tubers of Rural New Yorker No. 2, showing variation in position and depth of the terminal eyes or, as they are more generally known, the bud-eye cluster.

large plants. Tuber formation seems also to be delayed, but when the right growing conditions prevail, in the latter part of the season, they grow very rapidly and, if the season of favorable growth is prolonged, the larger tubers are quite apt to be hollow-hearted. As a group, the tubers are of desirable shape, attractive color, and fair table quality, and the vines are fairly resistant to drought and to diseases other than late blight.

As in the case of the Burbank group, two sections have been created in order to include the Russet Rurals, which, save for the color of the skin and a heavier netting, are practically identical in every other respect with those of the white-skinned varieties included in section 1, the one description answering for both.

Description.—Vines medium large. Primary stem upright, usually long-jointed, and rather sparsely covered with foliage;

FIG. 263.—Cross section of a Rural New Yorker No. 2 tuber. Natural size.

lateral branches more or less decumbent, giving the plant a straggly appearance. Stems more or less distinctly streaked with dark purple. Leaves medium-sized to rather small, dark green, more or less rugose or crumpled and leathery or firm to the touch. Flowers medium to fairly abundant in some varieties and of fair size; the central portion of the corolla deep violet-purple with the color growing lighter toward the outer portion; five points of the corolla white or nearly so. Tubers broadly round-flattened to short-oblong, or distinctly oblong-flattened (Figs. 261-263, Pl. III-I). Eyes few, very shallow, bud-eye cluster strong and usually depressed. Skin creamy-white and occasionally netted in the varieties of section 1, while in those belonging to section 2, the skin is a deep russet color and much netted. Sprouts short, base enlarged, dull white; leaf scales and tips medium to deep violet-purple or pansy-violet.

Section 1.

The varieties classified under section 1 seem to be, in most cases at least, the result of a re-naming of old varieties.

Arcadia.
Banner (Livingston's Banner).
Carman No. 3.
Dooley's.
Doolin, John.
Great Divide.
Hart's No. 1.
Improved No. 5.
Isle of Jersey.
Jackson White.
Late Beauty (Heath's L. B.).
Late Surprise (Heath's med.-late).
Late Victor.
Lily White.
Manila.
Market Prize. ‡
Million Dollar.
Nebraska.
Non-Blight.
Noxall.
Ohio Wonder.
Pan American.
Peerless (Bresee's No. 6) or Boston.§
Potentate.
Prince Henry.
Prosperity.
Rhind's Hybrid.
Rural New Yorker No. 2.
Sensation.
Sir Walter Raleigh.
Snowflake Jr. ‡
Todd's Wonder.
Uncle Sam. ||
White Giant.
White Swan.
White Globe.

Section 2.

Golden Harvest.
Golden Rule.
Golden Rural.
Late Petoskey (Rural Russet).
Russet Rural (Dibble's Russet).

Group 10.—The Pearl group is one of the smallest and at the same time one of the least known, so far as its origin is concerned. It is chiefly grown in Wisconsin, Nebraska, Colorado, and Idaho. There are three distinct types in the group, the first of which is

§ Not the true Bresee's Peerless, though listed as such.

‡ A. L. Dacy's Classification.

|| At the present time there seems to be two distinct varieties bearing the name of "Uncle Sam." One belongs to the Green Mountain and the other to the Rural Group. The original "Uncle Sam" is a member of the Green Mountain group

represented by the Pearl, the second by People's and the third by Blue Victor, from which the Pearl probably owes its origin as a bud variation or sport. The members of this group, like those of the Triumph and Green Mountain, are very susceptible to mosaic; and it is becoming increasingly difficult to produce or to purchase disease-free seed.

Description.—Maturing about with Green Mountain. Vines medium to large, strong, healthy and as a rule well-branched; stems dark green (in section 3 streaked with purple), more or less upright in early stages of growth, but gradually assuming a somewhat decumbent position as the plant approaches maturity. According to Fitch[2] the main stem of the Pearl should assume a more or less horizontal position, and the lateral branches an upright position. Leaves medium to large in size, rather flat, somewhat rugose, and approaching dark green when well grown. Flowers not abundant, and many of the buds that do form drop off either in the bud or just prior to opening; corolla is white with pale lemon-yellow stamens. When plants are normal, they do not, as a rule, produce many seed balls. Tubers in section 1 are medium to large in size and in favorable growing seasons often get large and of uneven shape. Normal tubers are round-flattened to heart-shaped flattened, usually heavily shouldered due to deep recession of stem (Figs. 264 and 265, and Pl. I-C). Eyes rather shallow, sometimes protuberant, or in off-type specimens inclined to be deep with heavy eyebrows. The bud-eye cluster in a normal specimen is shallow, while in an abnormal one it is usually distinctly depressed. When freshly dug, the Pearl has a distinct pinkish or light purple tinge around the eyes, particularly at the seed end; exposure to the light or prolonged storage seems to reduce the color to such an

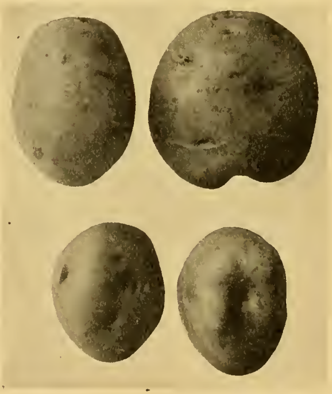


Fig. 264.—Four views of Pearl tubers.

extent that it is scarcely, if at all, visible. Skin a dull white, generally more or less netted. Sprouts have base, leaf scales and tips slightly or distinctly suffused with light lilac.

Section 2.—The tubers of the People's potato, which is the sole member of this section, are so nearly identical in every respect, except in color of skin, as to make it unnecessary to do more than describe the color which, when well grown in the lava ash soils of southern Idaho, is a rich russet-brown. The russet color is not due as in the case of the Russet Burbank, to a heavy, corky-brown growth, but rather to a coloration of the skin itself. It is the same kind of pigmentation as is found in some of the Russet Rural varieties, such as the Golden Rural.

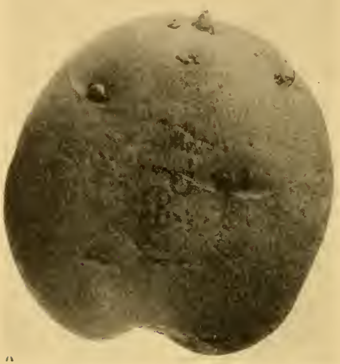


Fig. 265.—A very good type of the Pearl

Section 3.—The Blue Victor is the sole member of this section and its tubers differ from the Pearl in that they are a deep blue color, frequently with creamy-white splashes around the eyes. The sprouts, base, leaf scales and tips are a vinous-mauve.

The varieties belonging to the Pearl group are as follows:

Section 1.	*Section 2.*	*Section 3.*
Dearborn	People's	Blue Victor
Pearl		
Rehoboth		

The Dearborn and Rehoboth are considered identical with the Pearl.

Group 11.—The Peachblow group is an interesting one because it is the oldest of the twelve groups given. The "old-timer" or the potato grower of 50 years ago, usually harks back to the large yields and excellent table qualities of the Old Jersey Peachblow, and constantly regrets that it has been allowed to disappear. During the past half century or more a considerable number of Peachblow varieties have come and gone until, at the present time, there are practically but two members of this group that are now grown commercially in the United States. These varieties are the Improved Peachblow and the McCormick. The former is grown in a limited way in some sections in Colorado and the latter as a late crop throughout a large portion of the South, beginning with Maryland and extending to Georgia. This group is characterized by the extreme health and vigor of its vines. It includes some early varieties, but for the most part they are late to very late in maturing.

FIG. 266.—A fairly representative McCormick tuber. Note number and depth of eyes.

The McCormick is the most dependable variety that we have to grow as a late crop in the South, as it is the only variety that will successfully withstand the extreme heat, and occasionally extreme drought as well, and at the same time make a fair crop if rain and cool weather come early enough in the Autumn to give the necessary time for tuber development.

Description.—Vines strong, erect, healthy, vigorous and deep-rooted. Stems large, strong, woody, and medium green in color. Leaves medium in size and abundance, rather thick, rugose, or crumpled, medium to large in size and rather dark green. Flowers usually abundant, purple, and, in the case of the McCormick, inclined to set fruit rather freely when conditions are favorable.

Section 1.—The tubers are roundish or ovoid, to round-oblong, somewhat flattened. Eyes numerous and usually quite deep (Fig. 266, Pl. IV-J), invariably suffused with carmine or crimson, the intensity of which is more or less variable. Skin creamy-white to white splashed with crimson or magenta or flesh colored. Sprouts have base, leaf scales and tips of reddish-violet.

Section 2.—The tubers are round-flattened to heart-shape flattened. Eyes few, mostly at seed end, very shallow except bud-eye cluster, which is generally more or less depressed (Pl. IV-K). Skin a deep reddish-pink or magenta, carmine colored around the eyes. Sprouts similar to those in section 1.

Section 1.

Dykeman.
Early Peachblow (Hall's).
Extra Early Peachblow.
Jersey Peachblow.
McCormick (pink).
McCormick (white).

Section 2.

Improved or Perfect Peachblow (Rand's), Synonym. Red McClure.
New Improved Peachblow (Nichols').
New White Peachblow (Thorburn's).
White Peachblow.
Nott's Peachblow.

Group 12. The Up-to-Date group of potatoes is of European origin. The leading member of the group, Up-to-Date, was

FIG. 267.—A good type tuber of the Up-to-Date variety. Note fewness of eyes and general smoothness of tuber.

originated by Archibald Findlay of Scotland in the late eighties, and ranks among the leading late or main-crop potatoes of Great Britain. The Factor, introduced by Sutton and Sons of Reading, England, is so nearly identical with Up-to-Date as to be practically indistinguishable from it. Both of these varieties were introduced by the United States Department of Agriculture in the spring of 1905, and have been continuously grown in the Department's variety collection since that date. Within the past few years some varieties have been offered by seedsmen under American names that are very similar to Up-to-Date. The members of this group do not appear to have a very wide range of adaptation in this country, but where they have been tested under good environmental conditions, they have made a very satisfactory crop. They are best adapted to rather heavy soils, and to a rather cool climate, such as may be found in the Northwest, where it proved extremely satisfactory at the Western Washington Station, Puyallup, Washington.

Description.—Vines medium to large. Stems quite large, and woody, decidedly angular, dark green. Leaves medium size, rather thick, and having a peculiar twisted appearance; dark green. Flowers rose-purple, moderate to rather profuse bloomers; pistil thick and usually twisted or curved; stamens seldom if ever producducing viable pollen. Tubers oblong-flattened to somewhat obovate-flattened, usually of a good size. Eyes few, very shallow, mostly at seed end (Fig. 267, Pl. IV-L). Skin creamy-white, moderately netted or nearly smooth.

The following varieties have been classed in the Up-to-Date group by Henshaw.[3]

Col. Staney.
Conquering Hero.
Cottar.
Dalhousie Seedling.
Dalmeny Argon.
Dalmeny Beauty.
Dalmeny Helium.
Dalmeny Hero.
Dalmeny Regent.
Duchess of Buccleugh.
Duchess of Cornwall.
Dumfries Model.
Enquirer.
Factor.
Gen. Roberts.
Heather Blossom.
Highlander.
King Loth.
Motor.
Nobleman.
Scottish Monarch.
Scottish Triumph.
Sensation.
Sir Mark Stewart.
Superlative.
Table Talk.
Talisman.
Up-to-Date.
Warrior.

Only two of the foregoing varieties have come under the writer's observation, *viz.,* Factor and Up-to-Date. In addition to these, several varieties now listed by American seedsmen have been studied and assigned to this group. These are

Bull Moose.
Cumming's Pride.
Gold Standard.
Moreton.
Producer.
Pres. Roosevelt.
Solanum Sp. (from South America).
Verbots (from South America).

Bull Moose is quite popular in southern Indiana and in the Louisville district in Kentucky.

QUESTIONS ON THE TEXT

1. What scheme of classification was first advocated? By whom?
2. Give the next suggested system of classification. By whom?
3. How did the third system differ from the second one? By whom submitted?
4. Who was the first to devise a classification system in the United States?
5. On what was his grouping based? How many groups? Name them. How subdivided?
6. What changes did Kohler make in his later classification?
7. What variety classification did Ballou offer?
8. What variety classification did Milward present?
9. How does this classification compare with Kohler's?
10. How many groups did Fitch make in 1914? Name them.
11. In what respects is this an improvement?
12. Give Snell's classification.
13. Give author's (Stuart's) classification.
14. How does this differ from the preceding ones? How many groups?
15. What other character has been suggested by Kranz for the identification of the groups?
16. Of what value is the group system in studying varietal relationships?
17. Give the classification key offered in this chapter for each group.
18. What is said regarding group 12?
19. Give the chief characteristics of the Irish Cobbler group.
20. To what sections and climatic conditions is the Irish Cobbler best suited? Discuss it as an early truck crop.
21. What varieties or so-called varieties belong to this group?
22. Describe the Triumph group, and compare the members with those of the Irish Cobbler group.
23. Where is the Triumph most extensively grown?
24. What varieties or so-called varieties belong to this group?
25. Of what commercial importance is the Early Michigan group? Where chiefly grown?
26. Describe the Early Michigan group? Name the varieties.
27. How do the varieties belonging to the Early Rose compare in point of numbers to those of the other groups?
28. Of what importance is this group commercially?
29. Describe the sections of the Early Rose group.
30. What varieties belong to each?
31. Is there any general similarity between the Early Rose group and the Early Ohio group? Give differences.
32. Where is the Early Ohio most extensively grown? Give varieties.
33. Describe the Early Ohio, giving characteristics of plant and tuber.
34. In what respect do the varieties of the Hebron group differ from those of the Early Rose? Describe the former.
35. To what is the decadence of this group due? Give varieties.
36. Where is the Burbank group of potatoes commercially grown?
37. Name the sections of the group. Name varieties of each.
38. Describe and compare the two sections.
39. What sections and conditions best suit the Green Mountain group?
40. To what diseases are its members peculiarly susceptible? Describe the group.

41. Into how many sections is the group divided? Give basis of division.
42. What varieties belong to each section?
43. Describe the plant and tuber characters of the Rural group.
44. To what section of the country is it adapted?
45. Give the names of as many varieties as possible under section 1.
46. Name the varieties belonging to section 2.
47. For what is the Pearl group chiefly distinguished? Describe the group.
48. How many distinct tuber types are there in the group?
49. Distinguish between the sections.
50. Describe the People's potato.
51. Describe the Blue Victor.
52. Name the varieties belonging to the three sections.
53. How many real commercial varieties belong to the Peachblow group at the present time? Name them by sections.
54. What member of this group is especially adapted to the production of a late crop of potatoes in the South? How so adapted?
55. Describe the Peachblow plant and the tubers in sections 1 and 2.
56. What varieties belong to sections 1 and 2?
57. What is the history of the Up-to-Date group? Give adaptation.
58. Describe the vine and tuber characteristics.
59. Name the varieties included in this group which are or have been offered to the trade by American seedsmen.

QUESTIONS AND EXERCISES SUGGESTED BY THE TEXT

1. Make a rather complete list of the varieties of potatoes grown locally.
2. From dealers and growers obtain standard samples of each of these. Learn to know standard samples of leading varieties.
3. Determine from name, as well as from characteristics, to what group each belongs.
4. With these on exhibit plates, write labels on cards for each and include group names and synonyms. Learn to know the groups better by this exercise.
5. Prepare an appropriate premium list to cover all the groups and varieties likely to be grown in your county or state.
6. Make a large drawing showing plans for a large booth on potatoes at a fair.
7. Make up a list of several questions for debate on potato topics.
8. On one of these questions, concerning varieties, outline the arguments on both sides of the debate.

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APPENDIX

STUDENT'S PROJECT IN GROWING A FIELD OF POTATOES FOR PROFIT

In the following outline it is assumed that this project begins with fall preparation of the field, and continues through the cycle until the potatoes are stored and marketed the following fall and winter. If desired, the project may begin in the spring instead. The operations would be in the same order, and this outline would serve the same purpose.

The citations for study in the third column are to chapters in this volume. At the end of each chapter other references will be found.

Project operations.	*Study involved.*	*Citations to Chapters.*
Select field.	Desirable soil; warm or cold soil; physical texture of soil; moisture; fertility; best crop to precede potatoes.	III, IV, V.
Plowing.	Time of plowing: Advantages of fall plowing and conditions under which it may be inadvisable to do it.	IV.
Selection of suitable variety.	Compare varietal groups; varietal suitability to soil and climate; disease resistance; productivity; market requirements.	VII, XXI, XXII.
Source of seed stock.	Value of good seed; certified seed; sources of good seed; cheapness of good seed and costliness of poor seed.	VII.
Purchase of seed stock.	Why buy seed potatoes? Need of early purchase of seed; best method of storing seed during late fall and winter months.	VII, XIII.
Selection and purchase of commercial fertilizers.	Kind and amount of fertilizer to buy; coöperative buying. Desirability of early purchase.	V.
Home mixing of fertilizers.	Advantages of home mixing; methods; cost.	V.
Make winter study of diseases and insects.	Local enemies of the potato; nature and prevention of diseases, methods of combating insects; sprays to use; spraying apparatus; field treatments to prevent diseases and insects.	XV, XVI, XVII.

Make plans for storage pits and storage houses.	Principles of storage; drainage; temperature control; ventilation; light exclusion; materials needed; cost estimates per bushel capacity.	XIII, XIV.
Make winter study of markets.	Charting market prices in local and distant markets; compare prices for a series of years where possible; best time to market potatoes; relation to variety and season.	XII.
Preparation of land and application of fertilizer.	Plowing under green manure; barnyard manure; time of operation; benefits; depth of plowing; costs after treatment; marking or laying off rows; compare kinds of stable manure for potatoes; fresh or rotted.	IV, V.
Prepare seed.	Treatment of seed potatoes; quantity of seed to prepare per acre; greening; vitality; cutting; size of seed piece; holding cut seed; dusting cut seed.	VII.
Planting seed.	Time; methods; types of planters; distances; depths; fertilizing at planting time.	
Early tillage.	Pre-germination tillage; benefits; implements; methods; number of times.	VIII.
Tillage after germination.	Purposes; implements; frequency; depths.	VIII.
Combating enemies and controlling diseases.	Objects of spraying; materials; frequency of application; spray outfits; results.	XV, XVI, XVII.
Construction of storage house.	Review plans and lists of materials made; dimensions needed; location; probable cost of material and labor; advisability of building, etc.	XIII, XIV
Field selection of seed potatoes.	Object of field selection. How and when to select in field. Improvement by selection. Hill-to-row plan of improvement; mass selection; strain test; storing seed potatoes.	XXI.
Harvesting of crop.	Time; relation to market demands; transportation; prices; methods of harvesting; methods of picking; best containers; handling when harvested.	XII.
Marketing the crop.	Conditions of market; size and condition of crop both as a whole and locally; what portion to market at harvest time;	

	grading and sorting to size; containers for marketing; hauling; cost of marketing.	VII.
Storing crop, and advisability of same.	Methods of handling for storage; soundness of stock; danger of shrinkage; other risks; probable benefits of storage. When is storage not profitable?	XII, XIII.
Soil sanitation.	Crop rotation; crops to use for rotation purposes; connection between crop rotation and fungous and insect and animal pests; length of rotation; use of cover crops.	V, VI.
Cost accounting.	Cost of man and horse labor involved in the production of the crop; cost of seed potatoes; cost of fertilizers (chemical, stable, and green manures); cost of fungicides and insecticides; storage; marketing; rental of land; interest on money invested in crop; receipts from crop. Keep close record of every item of expense and income. Determine cost per bushel and per cent of profit. Study cost accounting.	XI.
Financial summary.	Prepare financial analysis from cost accounting data. Write in narrative form a complete record of procedure and results.	XI.

DEMONSTRATIONAL AND INSTRUCTIONAL FEATURES IN POTATO PROJECTS

1. When fighting potato beetles, compare spraying methods with dusting.
2. Compare yields from different kinds and amounts of commercial fertilizers, farm manure or green manure.
3. Compare results from selected and unselected seed.
4. Compare yields from different lots of seed of same variety from different sources or growers.
5. Plant rows respectively with one-eye, two-eye, many-eye pieces and whole tubers. Observe differences in number of stems and tubers per seed piece and of marketable tubers.
6. Test high ridging in comparison with almost level culture.
7. Compare results from untreated and treated seed.
8. Compare different varieties in regard to yields of marketable tubers.

POTATO EXHIBITS

Objects of Exhibits.—Until recently, the primary object of a potato exhibit seems to have been to gather together as large a collection of varieties, or so-called varieties, as was possible in any given section. The premium list was usually a long one and little attention was apparently given to duplication of varieties under different names. Each exhibitor was allowed to arrange his exhibit of potatoes along with any other vegetables or fruit that he might be displaying, and thus it came about that potatoes were scattered here and there throughout the exhibition hall, with no regard to the convenience of the public or the judges who had to pass upon their relative merits. Fortunately, such a system of displaying exhibition material, and of offering premiums for a nondescript collection of varieties is rapidly passing away.

The real object of holding an exhibition or show should be that of educating the public, by bringing together for their inspection and study, the most desirable varieties, properly named, and representing the best type specimens of the variety. The following suggestions are offered as an aid to such an accomplishment. The number or the quantity of tubers of each variety displayed should be uniform. If a plate exhibit is called for, the number of tubers should be specified; five or six tubers are sufficient. The peck display seems to have many adherents. Some potato associations, such as the Wisconsin Potato Growers' Association, provide wooden trays having just enough depth to permit of two layers of potatoes. All exhibits of a given variety should be assembled together, in order to permit of ease of study and comparison. No premiums should be offered on any but strictly commercial varieties, neither should a premium be offered on two varieties belonging to the same class or group, as for example Green Mountain and Gold Coin, or Rural New Yorker No. 2 and Carman No. 3.

Selecting and Preparing Exhibition Tubers.—In order to intelligently select exhibition tubers, the exhibitor must have a clearly defined ideal in mind. He must know what the ideal tuber shape and skin color of the variety is and he must also know what size will be given preference by the judges. The Wisconsin Potato Growers Association and many other State Associations now stipulate or suggest a certain weight of tuber. For example, Triumph 7 ounces, Irish Cobbler 7 to 8 ounces, Green Mountain and Rurals

9 to 10 ounces, etc. This furnishes the grower a cue as to the best size to select.

To secure tubers with an unbroken skin it is necessary to carefully hand-dig a large number of plants. The next step is to select a tuber having the ideal shape, appearance, and size and match it with others until a few more than the required number have been secured. Tubers intended for exhibit should be exposed to light as little as possible. As soon as selected they should be placed on a piece of paper or a sack, and allowed to dry off for a few minutes, after which they should be wrapped in paper and stored away in a cool, dark room until desired for exhibition purposes. In preparing them for exhibit remove the wrapper and brush them free of adhering soil with a soft brush, being careful not to break the skin. All tubers showing discolorations or other imperfections should then be discarded, and the remainder again wrapped and carefully packed for shipment to the show. Attention to these details will always insure attractive show material.

The Score Card as an Aid to Intelligent Judging of Exhibits.—The value of the score card in judging potato exhibits is now well recognized. Although a number of score cards are in use they do not vary to any material extent, they are all designed to serve as a basis for the correct interpretation of certain fundamental qualities of the potato by assigning to them a definite number of points, the sum total of which is 100.

Score Card.—The following score card is suggested as a guide and aid in judging potato exhibits:

I. Varietal purity.—(Free from mixture)	20 points
II. Conformity to type.—	
1. Shape: correct for variety and uniform	20 points
2. Size: desirable for variety and uniform	10 points
3. Color: correct for variety and uniform	5 points
4. Surface: skin and eye characters normal for variety	5 points
III. Condition and quality.—	
1. Clearness, brightness, freedom from mechanical injury	15 points
2. Quality of flesh, clear and firm, not spongy, free from streaks, discoloration and hollowness	10 points
3. Freedom from disease, scab, rhizoctonia, roots	15 points
Total	100 points

Suggested Descriptive Terms to be Used in Describing Potato Varieties.—The following descriptive data were prepared and presented at the Fourth Annual Meeting of the Potato Association of America, by the Association committee on varietal nomenclature and testing of the potato, in order to provide its members with a definite outline to be used as a guide in the description of varieties. (A complete report of this committee may be found in the *Proceedings of the Fourth Annual Meeting of the Potato Association*: 93-94, Nov. 9-10, 1917. Wm. Stuart, *Chairman*, A. L. Dacy, E. V. Hardenburg, C. L. Filch, R. Wellington, P. M. Lombard.)

In the use of such a descriptive sheet it is intended that all terms not applying to the particular variety under observation shall be crossed. For example, if the plant is large, cross out small and medium; or, if the tuber is oblong-flattened-rounded cross out all others on shape, or else place a check-mark opposite oblong-flattened-rounded.

Suggested Descriptive Terms to be Used in Describing Potato Varieties

PLANT CHARACTERS.

Size.—Small, medium, large.

Habit.—Upright, medium, spreading.

Stems.—Slender, medium, stout; little or much branched; slightly or distinctly angular; winged or smooth; wings wavy or straight; color light or dark green; much or little tinged with violet.

Leaves.—Sparse, abundant; small, medium, large.

Leaflets.—Narrow, medium, broad; smooth, hairy; light, medium or dark green.

Flowers.—None, few, medium, many; buds persistent or dropping before opening; corolla white, rose-purple, violet, lavender or blue.

Season of Maturity.—Very early, early, medium, late, very late.

General Information.—Source of seed.

Date secured.

Amount planted.

Size of seed, whole, cut, ... eyes, ... ozs.

Place.—Date planted,...., year,....

Distance between rows, ..., plants,......

Area in square feet.

Soil type.

Seasonal conditions; favorable, unfavorable.

Rainfall; scanty, normal, excessive.

Temperature at blossoming period; low, normal, high.

Date of maturity.

Date harvested.

Yield.—Marketable tubers, ...lbs.

Cull tubers,..... lbs.

Desirability of variety for section; for home use....; for market.........

Keeping quality of the variety; poor, medium, good.

Shipping quality of the variety; poor, medium, good.

Eating quality of the variety; poor, medium, good.

Resistance to late blight; none, little, much.

Resistance to common scab; none, little, much.

Resistance to other diseases; none, little much.

Observer.

TUBER CHARACTERS.

Size.—Small, medium, large; uniform, not uniform.

Shape.—Oblong—flattened—rounded.
Elleptical—flattened—rounded.
Oval—flattened—rounded.
Roundish—flattened.
Cubical—flattened.
Apical end rounded, blunt.
Basal end rounded, blunt, depressed, notched and shouldered.

Color of Skin.—Dull white, creamy-white; creamy-yellow; light or dark russet; light pink; red; magenta; mosaic; blue; bluish-black.

Texture of Skin.—Glossy, dull, smooth; uniformly netted; flaked.

Lenticels.—Few, medium, many; prominent, inconspicuous

Eyes.—Few, medium, many; uniformly distributed or mostly at apical (bud end; eyes shallow, medium, deep; eyebrows short, medium, long; curved or straight, curve simple or compound.

Sprouts.—Few, medium, many; slender, medium, stout; tips and leaf scales are creamy-white, pink, magenta, purple, violet-blue, or bluish-black; internodes are white, pink, magenta, purple, violet blue, or bluish-black; base white, pink, magenta, purple, violet-blue, or bluish-black; papillæ white, pink, magenta, purple, violet-blue, or bluish-black.

Cooking Test.—When the cooking and table qualities of different samples of potatoes are to be tested, it is extremely important that each lot of tubers should be baked or boiled under as nearly identical conditions as possible. The following method has been found to provide a uniform cooking test. Select three or four tubers of as nearly uniform size and shape as possible; boil each lot of tubers in separate saucepans or pots of the same shape and size; begin the test at the same time and boil them alike until done. In the baking tests select the tubers in the same manner, but place each lot in the same oven. Maintain the oven temperature as nearly as may be at 380 degrees F. until they are done. On removal from the oven, break or puncture the skin so as to allow the steam to escape. Remove the skin from all but one baked or boiled potato as quickly as possible after removal from pot or oven, and mash the flesh with a fork or potato masher to determine the fineness or grain of the flesh, its color and general appearance, and its pleasantness of taste, as determined by actual test of its eating qualities. This test should be made without the addition of butter or seasoning of any sort, in order to catch the true edible qualities of the tubers studied. Each remaining tuber should be set aside and allowed to get cold, after which it is to be re-warmed for the purpose of ascertaining to what degree the flesh retains its color and mealiness. The flesh of some varieties turns undesirably dark when re-warmed.

Points to be considered in judging the table qualities of potatoes are ease and uniformity of cooking; skin and flesh intact or nearly so when boiled; texture of flesh; character of grain when mashed; color of flesh; flavor. The following ratings have been found fairly satisfactory:

Ease of cooking	5 points
Uniformity of cooking	10 points
Skin and flesh intact when boiled *	10 points
Texture of flesh	15 points
Grain when mashed	15 points
Whiteness of mashed flesh	15 points
Flavor	30 points
Total	100 points

POTATO TRIPS

Trips to potato fields and elsewhere may be planned with profit. Students should be given an outline of the main features to be studied on each trip. They should prepare for the trip by reviewing these points. Notes should be made during the trip from which to write an account of the observations and lessons learned.

1. Visit fields for practice in choosing good potato soils.
2. Go to seed storage places and retail seed stores to study varieties, methods of handling, and protection and prices.
3. When large growers or others are preparing the soil for potatoes, visit the fields and take notes on methods.
4. Such places should also be visited when seed potatoes are being treated for scab and rhizoctonia, cut for planting, greening, etc.
5. Study planting machines of several kinds; if possible, when in actual operation in fields.
6. Study pre-germination tillage and after-tillage in potato fields.

* *Note.*—Waste, through rupturing of skin and sloughing away of flesh, may be entirely avoided by the use of a steam cooker.

7. Where Bordeaux mixture and other spray materials are being made for field work, make studies of methods and results. Study methods of spraying and dusting. If there are outbreaks of blight or other troubles examine them carefully.
8. At harvest time, study methods of harvesting, picking, handling, sizing, grading and record keeping.
9. Take trips to study store houses under construction or when in use. Draw their plans and make estimates of cost for material and labor. Visit cold-storage plants if possible.
10. Study operations at shipping points; grading, classifying, varieties, summer cars, winter cars, coöperative endeavors, record keeping, crediting.
11. If any kind of manufacturing plant using potatoes is near visit that and study methods, products and by-products.
12. Visit large retail and wholesale markets. Study good and bad handling, diseases, containers, grades, sizes, varieties, prices. Secure specimens and compare in knife tests: smooth to pare thin, flesh white or true to type, sound and rather dry, not hollow, cortical layer thick, central areas small, not watery.

List of varieties of potatoes, giving characteristics, groups, origin and reference for each.

Name of variety	Group number	Parentage	Date of introduction	Season	Vines:—strong or medium	Form of tuber	*Surface of tuber	Eyes:—deep, shallow	Color of skin	Color of flesh	Reference
Acme (Early Acme)......	5	Seedling of Snowflake	1894	e.	st.	o.	sm.	sh.	f.	w.	Vaughan's 1895 Cat.
Acme (Walker's).........	5	Triumph × Peerless		e.	st.				w.		Otto Schwill & Co's Cat. 1894, p. 50
Acorn.................		Ey. Sunrise × Brownell's 1894, Winner		m.	m.	ob.		m.	b.-w.	w.	R. N. Y. vol. 55, p. 850, 1896
Admiral Foote..........		Beauty of Hebron × Maggie Murphy	1902	m.	st.	ob.-f.	sm.	sh.	p.		S. D. Woodruff & Sons' Cat. 1902
Advancer Vick's Early....	6	Seedling of Late Beauty of Hebron				ob.-f.	sm.	sh.	w. p. eyes.		E. H. Vick's Cat. 1895, p. 6
Albino (Early Albino, Early White Albino)	3	Early Ohio × Snowflake	1887	e.	m.	l.-r.		m.	b.-w.		Angell & Co's Seed Cat. 1895, p. 27
Alpha.................		Early Rose × Sebec	1876	e.	m.	ob.-sl. f.	sm.	sh.	white with tinge r.e.	w.	B. K. Bliss & Sons' Circ. 1876
American Giant (Aroostook Wonder)	8-2		1881	m.	st.	l.-f.	r.	d.	b.-w.	w.	B. K. Bliss & Sons' Pot. Cat. 1881, p. 11
Am. Wonder............	7	Seedling of Wall's Orange	1892	m.	st.	l.-f.	sm.	sh.	w.	w.	Vick's Floral Guide 1892, p. 64
Aroostook Beauty........		Seedling of Early Rose	1893	e.	st.	sht.-ob.			rose		R. N. Y. vol. 52: 266
Babbitt................	8	Seedling of Norcross	1905	m.-l.	m.	r. to ob.			w.		Johnson's Cat. 1905, p. 17
Badger State............		Burbank × Wall's Orange	1889	m.-l.	st.	ob.		sh.	w.		Vaughan's Seed Cat. 1891, p. 26
Banner (Livingston's Banner)	9		1894	m.-l.	st.	ob. to sl.-f.		sh.	cr.-w.		Livingston's Seed Cat. 1894, p. 88
Banner.................				m.-l.	st.	l.-o. sl.-f.		sh.	br.-r.		F. Ford & Sons' Cat. 1888, p. 22
Beauty (Brownell's Beauty)		Early Rose × White Peachblow	1873	m.	m.	o.-sl. sl.-f.	sm.	sh.	r.	w.	B. K. Bliss & Sons' Pot. Cat. 1873, p. 4
Beauty of Hebron, Early..	6	Seedling of Garnet Chili	1878	m.-e.	m.	l.-f.		sh.	c.w.&p	w.	Gregory's Cat. 1879, p. 55
Beauty of Hebron, Late...	6	Sport of Beauty of Hebron, Early	1881	m.-l.	m.	ob.-f.		sh.	c.w.&p	w.	Bliss & Sons' Cat. 1881 p. 8
Belle..................			1881	l.				sh.	d.-f.		F. Ford's Cat. 1882, p. 13
Bethel Beauty..........	8			l.	st.	ob.-f.		m.	w.	w.	New England Homestead 1911, p. 477
Bill Nye...............		Seedling of Beauty of Hebron	1891	m.	m.	ob.-f.	sm.	sh.	b.-w.	w.	A. W. Livingston's Cat. 1891, p. 11
Blight Proof...........	8			l.	st.	ob. f.		m.	b.-w.	w.	R. N. Y. vol. 55: 231, 1896
Blightless, (Late Blightless)	8			l.	st.	ob. to l.-f.		d.	b.-w.	w.	
Blightless Wonder........	8			l.	st.	l.	sm.		s.-c.	w.	Smith Bros. Seed Co's. Cat. 1911, p. 10
Blue Victor............	10			l.	st.	r. to h.-s	sm.	sh.	blue		R. N. Y. vol. 44: 10, 1885
Blush (Rural Blush, New Blush)			1882	m.-l.	st.	r. to ob.	sm.	sh.	f.	w.	R. N. Y. vol. 41. p. 569; F. Ford & Sons' Seed Cat. 1884, p. 15

List of varieties of potatoes, giving characteristics, groups, origin, and reference for each.

Name of variety	Group number	Parentage	Date of intro-duction	Season	Vines:—strong or medium	Form of tuber	*Surface:—rough or smooth	Eyes:—deep or shallow	Color of skin	Color of flesh	Reference
Bovee (Early Bovee)	6		1897	e.	m.	l.-o.	sm.	m.	p. or flesh	w.	R. N. Y. vol. 53, p. 490, 1894
Brownell's Best		Seedling of Excelsior	1882	m.-e.	st.	ob. sl. f.		sh.	w.	w.	B. K. Bliss & Sons' Pot. Cat. 1882, p. 6
Burbank's Seedling	7	Seedling of Early Rose	1876	m.-l.	st.	l.-r.	sm.	sh.	w.	w.	J. J. H. Gregory's Cat. 1876, p. 51
Carman No. 1	8		1894	m.	st.	r. to ob.-f.	sm.	sh.	w.	w.	R. N. Y. vol. 50: 756, 1891
Carman No. 3	9		1895	l.	st.	r. to ob.	sm.	sh.	cr.-w.	w.	J. M. Thorburn's Cat. 1895, p. 10
Charles Downing (Idaho Rural)			1887	e.	st.	ob.-o.	sm.	sh.	w.	w.	Ford & Sons' Cat. 1887, p. 16 Tillinghast's Cat. 1887, p. 16
Chicago Market	5	Early Goodrich × Early Rose	1879	e.	st.	o. to cyl.	sm.	sh.	l.-f.	w.	Vick's Floral Guide, 1880, p. 86
Clark's No. 1	4	Seedling of Early Rose 1876		e.	st.	sim. to par.					B. K. Bliss & Sons' Pot. Cat. 1881, p. 15
Clyde	8	Norcross × Green Mountain 1902	1906	m.-l.	st.	o.-sl. f.	sm.	sh.	w.	w.	Ref. Johnson's letter, 3-21, 1908
Columbus	6		1893	m.-e.	st.	l.-o.	sm.	sh.	l.-f.		F. Ford & Sons' Cat. 1893, p. 36
Country Gentleman	6		1896	m.-l.	m.-st.	ob.	sm.	sh.	blush & w.	w.	G. W. P. Jerrard Co's. Cat. 1896, p. 2
Dakota Red			1883	l.	st.	l.-r.			r.-f.	w.	Hiram Sibley & Co's. Cat. 1883, p. 123
Dakota Seedling			1888	l.	st.	ob.	sm.	sh.	p.	w.	Delano Bros'. Cat. 1890, p. 13
Dearborn	10		1912	m.	st.	nly. r.	n.	sh.	b.-w.	w.	Vaughan's Seed Cat. 1912, p. 7
Delaware	8	Early Rose × Excelsior	1888	m.-e.	m.	l. and r.	n.	m.	w.	w.	J. J. H. Gregory's seed Cat. 1888, p. 4
Early Harvest			1892	e.		o. f. to l.-o.		sh.	w.		G. W. P. Jerrard Co's. Cat. 1892, p. 2
Early Harvest	6	Seedling of White Elephant		m.-e.		o. to l.			cr.-w. and p.		Moore & Simons' Cat. 1907, p. 43
Early Maine	4	Seedling of Early Rose	1884	e.	st.	cyl. to eggshp		sh.	d.-f.	nearly white	R. N. Y. vol. 43: 794, 1884
Early Manistee (Imp. Manistee)	4-2	Seedling of Early Rose	1904	m.-e.	st.	r. to o.		sh.	l.-p.	w.	E. F. Dibble's Cat. 1904

Early Market	5		1889	e.		o.-ob.		sh.	f.-c.	w.	Vick's Floral Guide 1889, p. 85
Early Mayflower		Snowflake × Peachblow 1877	1883	e.	st.	oval sl. flat	sm.	sh.	cr.-w.	w.	R. N. Y. vol. 42: 177, 1882
Early Michigan	3		1895	m.-e.	m.	elong.	sm.	sh.	w.	w.	H. N. Hammond Seed Co's. Cat. 1897, p. 2
Early Norther	4	Seedling of Early Rose	1892	e.	st.	ob.-f.		sh.	d.-f.		G. W. P. Jerrard Co's. Cat. 1894, p. 4
Early Ohio	5	Seedling of Early Rose 1871	1875	e.	st.	ov.	sm.	sh.	f.	w.	J. J. H. Gregory's Cat. 1875, p. 47
Early Rose	4	Seedling of Garnet Chili 1861	1867-8	e.	st.	elong. f.	sm.	sh.	d.-f.		B. K. Bliss & Sons' Cat. 1869, p. 58
Empire State	8-2	Seedling of White Elephant 1881	1885	m.-l.	st.	ob.		sh.	w.	w.	R. N. Y. vol. 44: 265, 1885
Enormous (North Star)	8	State of Maine × White Star		l.	st.	ob.		m.	w.	w.	
Eureka		Excelsior × White Peachblow, 1871	1875	m.-e.	st.	ob.-ov.	sm.	sh.	w.	w.	Cult. & C. Gent. vol. 39: 580, 1874
(Brownell's Eureka) Eureka			1891	m.	st.	ov. or nly.r.		sh.	w.		F. Ford & Sons' Cat. 1891, p. 34
Eureka (Ex. Early Eureka)	1	Sport of Early Morn, 1895	1901	e.	st.	sh.ob.	sm.	sh.	w.	w.	W. A. Burpee's Farm Ann. 1901, p. 29
Everitt				m.-e.	st.	r.to o.		sh.	l.-r.		F. Ford & Sons' Cat. 1889, p. 26
Excelsior		Seedling of State of Maine	1868	l.	st.	nly..r	sm.	sh.	w.		J. J. H. Gregory's Cat. 1869, p. 21
Excelsior (Early Excelsior)	5	Seedling of Early Ohio		e.					f.		Young & Halsteds' Cat. 1905, cover page
Excelsior (Ex. Early Excelsior)				ex.-e.		sh.ob.	sm.		w.		Alston's Cat. 1902, p. 7
Extra Early (Burpee's Ex. Early)		Seedling of Early Rose	1889	ex.-e.		br. ob.	sm.	sh.	cr.-w. p.tge.		Burpee's Ann. 1889, p. 97
Farmer (Farmer Hastings)	8			l.	st.	ob.		sh.	w.	w.	J. L. Child's Cat. 1911
Fillbasket			1889	m.		ob.			w.		Howe's Pot. Manual 1889
Fillbasket (Ex. Early Fillbasket)		Snowball × Quick Crop		e.		elong.	sm.		p. or. f.	w.	Moore & Simons' Cat. 1906, p. 41
Freeman	8	Seedling of Silver Tip, 1885	1891	m.		ob.		sh.	w.-rus.	w.	W. H. Maule's Cat. 1891, p. 61
Flourball (Johnson's Flourball)	1			e.		r.			w.	w.	Johnson Seed Co's. Pot. Cat 1910, p. 47
Garnet Chili		Seedling of Rough Purple Chili	1857	l.	st.	r. to ob.		m.	bk.-r.	w.	Country Gent. vol. 22: 155, 1863
Gem of Aroostook	6	Seedling of New Queen, 1892	1898	m.	st.	elong. -ov.-f.			l.-m.		G. W. P. Jerrard Co's. Cat. 1898, p. 2
Gold Coin	8		1903	m.-l.	st.	brd.-ob.	sm.	sh.	w.	w.	W. A. Burpee's Farm Ann. 1903, p. 26-29
Golden Russet	7-2	Seedling of Early Ohio	1911	m.	st.	l.-cy.	netted	sh.	rus.	w.	L. L. Olds Seed Co's. Cat. 1912, p. 29

List of varieties of potatoes giving characteristics, groups, origin, and reference for each.

Name of variety	Group Number	Parentage	Date of introduction	Season	Vines:— strong or medium	Form of tuber	Surface:— rough or smooth	Eyes:— deep or shallow	Color of skin	Color of flesh	Reference
Great Divide	9	Early Ohio × California 1887	1894	m.-l.	st.	r.-ob.	sm.	sh.	w.	w.	W. A. Burpee's Farm Ann. 1894, p. 30-31
Green Mountain	8	Dunmore × Excelsior, 1878	1885	m.-l.	st.	ob.	sm.	sh.	w.	w.	R. N. Y. vol. 43: 729, 1884
Green Mountain Jr.	8	Seedling of Green Mountain 1905		l.	st.	r. to ob.		sh.	w.	w.	Johnson Seed Co's Pot. Cat. 1911, p. 5
Harbinger	6	Seedling of New Queen 1886	1890	m.	st.	el.	sm.	sh.	l.-f.		R. N. Y. vol. 49: 150, 1890
Heavyweight (Everitt's Heavyweight)				l.	st.	ob.	sm.		l.-r.		J. A. Everitt's 'Spec. Cat. 1896, p. 17
Heavyweight, (Mill's Heavyweight)	9			l.	st.	r. to ob.	sm.	sh.	w.		F. B. Mill's Cat. 1902, p. 32
Hoosier (Not syn. of McCormick)	6	Seedling of Beauty of Hebron	1894	m.-e.		ob.-f.		sh.	cr.-w. and p.		Huntington Seed Co's. Cat. 1895, p. 5
Irish Cobbler	1	Sport of Early Rose (about) 1876		e.	st.	s.-ob.		d.	cr.-w.		Gregory's Cat. 1899, p. 4
Jersey Peachblow (Old Jersey Peachblow)	11	Seedling of Western Red or Chenango, 1850		l.					r.	y.	Country Gent. vol. 26: 315, 1865
Jones Pink-Eyed Seedling			1912	l.		ob.			p.		O. S. Jones Seed Co's. Cat. 1912, p. 32
Joseph			1896	m.		ov.-sl.-f.			p.	w.	L. L. Old's Cat. 1897, p. 5
June Eating (Craine's June Eating)		Seedling of Eureka, 1884		e.	st.	ob. to l.			w. pr.		Ford & Sons' Cat. 1887, p. 17 "Harbinger" line
Keeper (Craine's Keeper)		Seedling of Eureka, 1883		m.	st.	el. r.		sh.	w.	w.	F. Ford & Sons' Cat. 1887, p. 17
Keystone	8	Seedling of Carman No. 1901		m.-l.	st.	l.			w.	w.	Vaughan's Cat. 1911, p. 7
Klondike	9	Seedling of R. N. Y. No. 2	1898	l.	st.	r. to ob.	sm.	sh.	w.	w.	Ki-Ote Seed Co's. Cat. 1898
Knowles (Knowle's Big Cropper)				m.	st.	ob.	sm.	sh.	w.	w.	J. J. H. Gregory's Cat. 1908, p. 6
Late Ohio	5			m.-e.		ob.		sh.	l. r. or p.		J. J. H. Gregory's Cat. 1880, p. 53
Lee's Favorite	4	Seedling of Early Rose	1883	e.		cyl. to ob.		m.	l.-f.		F. Ford Seed Co's. Cat. 1883, p. 13-14
Lightning (Crine's Lightning)		Early Ideal × Early Ohio and Early Rose (?)	1902	ex.-e.	st.	ob.			br. r.		Jos. Harris Co's Rural Ann. 1903, p. 35
McCormick (Late Hoosier, Lookout Mountain)			1882	v.-l.	st.	r.-ob.	r.	d.	flesh-p. eye	cr. w.	R. N. Y. vol. 44: 175, 1885

Maggie Murphy (Queen of the West)		Seedling of Wall's Orange	1893	l.	st.	ob.		d.	p.		Vick's Floral Guide 1893, p. 15
Magnum Bonum				e.	st.	nly. r.			w. p.eyes		F. Ford's Cat. 1882, p. 14
Mammoth Pearl			1879	m.	st.	nly. r	sm.	sh.	w.		B. K. Bliss & Sons' Pot. Cat. 1880, p. 15
Money-Maker	7			m.-l.	st.	l.-r.	sm.	sh.	w.		E. F. Dibble's Seed Cat. 1895, p. 13
New Queen	6	Seedling of Beauty of Hebron	1884	e.		el.-f.			cr.-w. and p.		J. J. H. Gregory's Cat. 1889, p. 5
Norcross	8	Early Rose × Beauty of Hebron, 1895.		m.-l.	st.	ob.-sl. f.	sm.	sh.	w.		Johnson Co's. Seed Pot. Cat. 1905, p. 12
Noroton Beauty (Quick Lunch)	2	Seedling of Old White Peachblow	1904	e.	m.	r.		m.	f and car.		J. M. Thorburn & Co's. Cat. 1905, p. 4
North Star		Early Ohio × Mammoth Pearl				r.		m.	buff		R. N. Y. vol. 43: 250, 1884
Noxall	9		1911	l.		r. to ob.	sm.	sh.	cr. w.		Wernich Seed Co's. Cat. 1911, p. 43
Ohio Junior	5	Seedling of Early Ohio 1881	1887	e.	st.	ov. to ob.	sm.	sh.	f.		L. L. Old's Cat. 1891, p. 4 Vick's Floral Guide 1887, p. 164
Orange (Wall's Orange)			1882	l.	st.	ob.-f.			org. and p.	w.	Cult. & Count. Gent. vol 47: 231, 1882
Pan American				ex.-e.		ob.		sh.	br. p.		C. S. Hopkin's Cat.1901,p.18
Pan American	9			l.		r.-f.	sm.	sh.	w.		Jos. Harris Co's. Cat. 1915. p. 49
Peachblow, (Extra Early Peachblow)	11	Early Vermont × White Peachblow	1881	ex.-e.		r.-f.			r.-w. p. eye		B. K. Bliss & Sons' Cat.1881. p. 6
Peachblow (Perfect Peachblow)	11			l.		r.		sh.	l. p.		Henderson & Co's. Cat 1887, p. 16
Peachblow (Thorburn's New White Peachblow)	11	Seedling of Excelsior			st.				w.	w.	J. M. Thorburn & Co's. Cat. 1897, p. 10
Pearl (Peerless)	10	Supposed to be sport of Blue Victor		m.-l.	st.	r.-f.	sm.	sh.	b.-w.	w.	
Pearl of Cannon Valley			1903		st.	ob. or nly.ov.		sh.	cr.-w.		Farmer Seed Co's. Cat. 1903, p. 8
Peerless, (Bresee's No. 6)		Seedling of Garnet Chili 1862	1870	m.-l	st.	r. to ob.	m.	m.	dull w.	w.	B. K. Bliss & Sons' Cat. 1870, p. 80
People's	10	Minnesota Seedling × Pearl of Savoy	1890	m.-l.	st.	ov. to r.-ob.		sh.	r.	w.	F. Ford & Sons' Cat. 1890, p. 28
Pingree		Seedling of Green Mountain 1894		e.	st.		sm.	sh.	w.		Northrup, King & Co's. Cat. 1898, cover page
Potentate	1			e.		r. to ob.			w.	w.	Frank Ford & Sons' Cat. 1885, p. 13
Pride of Multnomah	7		1909	m.-l.	st.	elong.		sh.			Portland Seed Co's. Cat. 1909, p. 56

List of varieties of potatoes, giving characteristics, groups, origin, and reference for each.

Name of variety	Group Number	Parentage	Date of introduction	Season	Vines:—strong or medium	Form of tuber	*Surface rough or smooth	Eyes:—deep or shallow	Color of skin	Color of flesh	Reference
Producer	12			l.	st.	ob.		sh.	w.		Portland Seed Co's. Cat. 1917, p. 35
Prolific Bresee's (Bresee's No. 2)		Seedling of Garnet Chili, 1861	1869	m.	m.	ob. sl. f.		sh.	w.sl. p. eyes	w.	The Horticulturist, vol. 24: 50, 1869
Prosperity	9	Seedling of Early Sunrise 1900		l.	st.	s.-ob.	sm.	sh.	cr.-w.	w.	F. W. Bolgiano's Cat. 1902 p. 34
Puritan Early		Seedling of Beauty of Hebron, 1882	1888	e.	st.	ob. to ov.	sm.	sh.	w.		Henderson's Cat. 1889, p. 8
Puritan Late		Sport of Early Puritan, 1889	1891	m.-l.	st.	ob. to ov.	sm.	sh.	w.		Peter Henderson & Co's Cat. 1892, p. 7
Quick Lunch (Noroton Beauty)	2	Seedling of Peachblow, 1890	1905	ex-.e.	m.	r.		sh.	cr.-w. and c.		W. A. Burpee's Farm Ann. 1905, p. 22
Rural New Yorker No. 2. (Carman No. 2)	9		1889	l.	st.	r. to ob.	sm.	sh.	cr. w.	w.	J. M. Thorburn& Co's Cat. 1889, p. 8
Russet Burbank (Netted Gem, Cal. Russet)	7-2	Supposed to be a Sport of Burbank		m.-l.	st.	elong. cyl.	n.	sh.	r.	w.	Farmers' Seed Co's. Cat. 1908, p. 34 Hammond Seed Co's. Cat. 1901, p. 16
Russet Rural (Late Petosky, Dibble's Russet)	9-2			l.	st.	r. to ob.	n.	sh.	r.	w.	E. F. Dibble's Farm Seed Cat. 1912, p. 4
Rustproof	8-2			l.	st.	ob.		sh.	w.	w.	
Seneca Beauty			1888	m.-l.	st.	l.-ov.	sm.	sh.	p.	w.	A. W. Livingston's Cat. 1890, p. 10
Silver Skin		Early Rose × White Peachblow	1880	m.-e.	st.	ov. to ob.	sm.	sh.	w.	w.	B. K. Bliss & Sons' Cat. 1881 p. 13
Sir Walter Raleigh	9	Seedling R. N. Y. No. 2	1897	l.	st.	r. to ob.	sm.	sh.	cr.-w.	w.	P. Henderson's Cat. 1897, p. 12
Snow	8			m.-l.	st.	ob.	sm.	sh.	w.	w.	
Snowflake		Early Rose × White peachblow, 1869	1873	m.	m.	elong. ov.	sm.	sh.	w.	w.	B. K. Bliss & Sons' Cat. 1874, p. 3
Spaulding No. 4	4-2			m.	st.	ob.		m.	l. p.		Ross Bros.' Cat. 1904, p. 24
Star of the East	6	Dewey × Johnson's No. 1	1905	m.	st.	ob.		d.			Johnson's Seed Pot. Cat. 1905 p. 19

State of Maine..........	8-2	Early Vermont × Peerless	1884	m.	st.	elong. cyl.		b.-w.			D. Landreth & Sons' Cat. 1884, p. 55
Surprise (Early Surprise)	1		1902	e.	st.	r.		sh.	w.	w.	R.N.Y. vol. 42: 718, 1883 G. W. P. Jerrard & Co's. Cat. 1903, p. 2
Thorburn..............	4	Seedling of Beauty of Hebron	1886	m.	st.	ob. to cyl.		sh.	w.	w.	J. M. Thorburn & Co's. Cat. 1886. p. 32
Triumph (Bliss Triumph, Red Bliss)............	2	Peerless × Early Rose.....	1878	ex.-e.	m.	r.	sm.	m.	l.-r.	w.	B. K. Bliss & Sons' Cat. 1878. p. 13
Uncle Sam................	8			m.-l.	st.	ob.	sm.	sh.	w.	w.	Peter Henderson & Co's. Cat. 1896. p. 12
Victor (Early Victor)......	1		1903	e.	st.	r.		m.	cr.-w.		Vick's Garden & Fl. Guide, 1903, p. 7
White Elephant (Late Beauty Hebron)........	6	Garnet Chili × White Peachblow	1881	m.	st.	ob.-f.		m.	cr.-w. p.tge.		J. M. Thorburn & Co's Cat. 1881, p. 30
White Harvest (Gurney's White Harvest)........	8			m.	st.	ob.-f.		m.	w.	w.	Gurney Seed & Nursery Co's. Cat. 1912, p. 65
White Mammoth (Whiton's White Mammoth)......	8	Seedling Old Peachblow	1900	l.	st.	ob.			w.	w.	H. Philipp's Seed Co. Cat. 1900
White Ohio (New White Ohio, Red River, White etc..................	5	Sport of Early Ohio, 1892		m.-e.	st.	ov.			w.-sl. p. eyes	w.	Vick's Floral Guide, 1896, p. 31
White Rose.............	4			m.-l.	st.	el.-ov.		sh.	w.		F. Ford's Cat. 1881, p. 13
White Star.............	7	Excelsior × White Peachblow	1881	m.-e.	st.	ob.	sm.	sh.	w.	w.	B. K. Bliss & Sons' Pot. Cat. 1881, p. 6
World's Wonder	9	Seedling Carman No. 3, 1898		m.-l.	st.	r.			w.		O. K. Seed Store Cat. 1910, p. 9

Key to abbreviations: Season—e, early; ex, extra; l, late; m, medium; v, very.
Vines—m, medium; st, strong.
Form of Tuber—brd, broad; cy, cyl, cylindrical; el, elong, elongated; f, flat; h-s, heart-shaped; l, long; nly, nearly; ob, oblong; o, ov, oval; par, parent; r, round; sh, sht, short; shp, shape; sim, similar; sl, slightly.
Surface of Tuber—m, medium; n, netted; r, rough; sm, smooth.
Eyes—d, deep; m, medium; sh, shallow.
Color of Skin—b, buff; bk, brick; br, bright; car, carmine; c, color; cr, creamy; d, dark; f, flesh; l, light; org, orange; p, pink; pr, purple; r, red or reddish; rus, russeted; s-c, straw color; sl, slightly; tge, tinge; w, white.
Color of Flesh—cr, creamy; y, yellow; w, white.

*Yearly and average acreage and production by States for the years 1915 to 1919 inclusive**

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
New York	1915	355,000	22,010,000	62.	$ .82
	1916	320,000	22,400,000	70.	1.58
	1917	400,000	38,000,000	95.	1.30
	1918	380,000	37,240,000	98.	1.22
	1919	363,000	39,567,000	109.	1.45
Average		363,600	31,843,400	87.6	
Minnesota	1915	285,000	30,210,000	106.	.39
	1916	280,000	16,800,000	60.	1.30
	1917	300,000	33,600,000	112.	.91
	1918	312,000	32,760,000	105.	.75
	1919	300,000	26,100,000	87.	1.53
Average		295,400	27,894,000	94.4	
Wisconsin	1915	298,000	25,926,000	87.	.45
	1916	290,000	13,630,000	47.	1.47
	1917	307,000	34,998,000	114.	.90
	1918	304,000	33,440,000	110.	.80
	1919	300,000	28,200,000	94.	1.40
Average		299,800	27,238,000	90.9	
Michigan	1915	355,000	20,945,000	59.	.56
	1916	320,000	15,360,000	48.	1.60
	1917	378,000	35,910,000	95.	1.05
	1918	340,000	28,560,000	84.	.89
	1919	326,000	28,688,000	88.	1.35
Average		343,800	25,892,000	75.3	
Maine	1915	142,000	25,418,000	179.	.70
	1916	125,000	25,500,000	204.	1.42
	1917	150,000	18,750,000	125.	1.30
	1918	112,000	22,400,000	200.	1.20
	1919	102,000	24,480,000	240.	1.40
Average		126,200	23,309,600	184.7	
Pennsylvania	1915	280,000	20,160,000	72.	.75
	1916	272,000	19,040,000	70.	1.48
	1917	321,000	29,532,000	92.	1.35
	1918	275,000	22,000,000	80.	1.51
	1919	254,000	25,400,000	100.	1.54
Average		280,400	23,226,000	82.8	

* The data in this table were taken from the December (1916 and 1919) Monthly Crop Report of the Bureau of Crop Estimates of the U. S. Department of Agriculture. These data do not in all cases coincide with those given in the Department Yearbook, as they represent revised estimates based on more complete information.

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Virginia	1915	140,000	17,500,000	125.	$ .61
	1916	125,000	16,250,000	130.	1.37
	1917	175,000	17,325,000	99.	1.25
	1918	135,000	12,690,000	94.	1.20
	1919	121,000	11,495,000	95.	1.57
Average		139,200	15,052,000	108.1	
California	1915	78,000	10,140,000	130.	.75
	1916	75,000	10,575,000	141.	1.40
	1917	105,000	15,225,000	145.	1.50
	1918	90,000	12,870,000	143.	1.20
	1919	88,000	11,352,000	129.	1.71
Average		87,200	12,032,400	137.9	
Ohio	1915	153,000	12,546,000	82.	.70
	1916	140,000	6,300,000	45.	1.82
	1917	160,000	16,000,000	100.	1.43
	1918	160,000	11,040,000	69.	1.50
	1919	150,000	9,300,000	62.	1.92
Average		152,600	11,037,200	72.3	
New Jersey	1915	93,000	12,090,000	130.	.75
	1916	85,000	10,370,000	122.	1.55
	1917	98,000	11,172,000	114.	1.41
	1918	117,000	10,764,000	92.	1.70
	1919	110,000	10,560,000	96.	1.69
Average		100,600	10,991,200	109.2	
Illinois	1915	126,000	13,860,000	110.	.59
	1916	125,000	7,250,000	58.	1.79
	1917	150,000	13,500,000	90.	1.52
	1918	160,000	11,520,000	72.	1.48
	1919	155,000	8,060,000	52.	1.96
Average		143,200	10,838,000	75.7	
Colorado	1915	53,000	7,155,000	135.	.55
	1916	50,000	6,900,000	138.	1.35
	1917	80,000	12,800,000	160.	.91
	1918	99,000	15,840,000	160.	.99
	1919	92,000	11,040,000	120.	1.70
Average		74,800	10,747,000	143.7	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Nebraska	1915	110,000	11,550,000	105.	$ .42
	1916	105,000	7,665,000	73.	1.50
	1917	147,000	12,495,000	85.	1.07
	1918	121,000	10,406,000	86.	1.18
	1919	115,000	6,325,000	55.	1.90
Average		119,600	9,688,200	81.0	
Iowa	1915	120,000	12,600,000	105.	.54
	1916	115,000	4,830,000	42.	1.75
	1917	138,000	13,110,000	95.	1.31
	1918	128,000	9,216,000	72.	1.33
	1919	115,000	4,945,000	43.	1.92
Average		123,200	8,940,200	72.5	
Washington	1915	61,000	8,235,000	135.	.53
	1916	60,000	9,900,000	165.	.98
	1917	79,000	9,875,000	125.	.92
	1918	63,000	8,316,000	132.	1.01
	1919	58,000	7,250,000	125.	1.45
Average		64,200	8,715,200	135.8	
Missouri	1915	90,000	8,820,000	98.	.60
	1916	91,000	5,460,000	60.	1.80
	1917	109,000	9,483,000	87.	1.37
	1918	114,000	6,954,000	61.	1.53
	1919	110,000	8,250,000	75.	1.84
Average		102,800	7,793,400	75.8	
North Dakota	1915	80,000	7,200,000	90.	.41
	1916	75,000	6,975,000	93.	1.15
	1917	90,000	3,870,000	43.	1.30
	1918	92,000	9,108,000	99.	.73
	1919	90,000	5,670,000	63.	1.60
Average		85,400	6,564,600	76.9	
South Dakota	1915	68,000	7,820,000	115.	.35
	1916	65,000	4,290,000	66.	1.37
	1917	80,000	7,200,000	90.	1.11
	1918	95,000	8,645,000	91.	.93
	1919	90,000	4,500,000	50.	1.90
Average		79,600	6,491,000	81.5	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Indiana	1915	75,000	7,125,000	95.	$ .56
	1916	74,000	3,256,000	44.	1.77
	1917	92,000	8,464,000	92.	1.39
	1918	108,000	8,640,000	80.	1.35
	1919	100,000	4,400,000	44.	1.95
Average		89,800	6,377,000	71.0	
Oregon	1915	48,000	5,520,000	115.	.60
	1916	55,000	8,250,000	150.	.90
	1917	75,000	8,100,000	108.	.80
	1918	50,000	5,500,000	110.	1.00
	1919	45,000	4,230,000	94.	1.50
Average		54,600	6,320,000	115.8	
Kentucky	1915	51,000	6,426,000	126.	.55
	1916	49,000	4,116,000	84.	1.42
	1917	70,000	6,720,000	96.	1.40
	1918	75,000	5,625,000	75.	1.65
	1919	72,000	5,040,000	70.	2.10
Average		63,400	5,585,400	88.1	
West Virginia	1915	50,000	5,850,000	117.	.65
	1916	48,000	4,224,000	88.	1.58
	1917	55,000	6,325,000	115.	1.32
	1918	55,000	4,785,000	87.	1.60
	1919	57,000	5,130,000	90.	1.75
Average		53,000	5,262,800	99.3	
Montana	1915	39,000	6,045,000	155.	.50
	1916	39,000	4,875,000	125.	1.20
	1917	57,000	5,415,000	95.	1.02
	1918	50,000	6,750,000	135.	.80
	1919	47,000	2,820,000	60.	1.60
Average		46,400	5,181,000	111.7	
Idaho	1915	28,000	3,500,000	125.	.56
	1916	27,000	4,050,000	150.	1.27
	1917	39,000	6,084,000	156.	.79
	1918	34,000	6,290,000	185.	.81
	1919	36,000	5,400,000	150.	1.51
Average		32,800	5,064.800	154.4	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Kansas	1915	71,000	5,893,000	83.	$ .74
	1916	70,000	4,970,000	71.	1.65
	1917	78,000	4,446,000	57.	1.52
	1918	80,000	4,240,000	53.	1.44
	1919	68,000	5,168,000	76.	1.90
Average		73,400	4,943,400	67.3	
Maryland	1915	44,000	4,268,000	97.	.62
	1916	43,000	4,085,000	95.	1.33
	1917	60,000	6,000,000	100.	1.19
	1918	53,000	4,240,000	80.	1.20
	1919	55,000	5,170,000	94.	1.30
Average		51,000	4,752,600	93.2	
North Carolina	1915	35,000	3,150,000	90.	.73
	1916	34,000	3,230,000	95.	1.40
	1917	50,000	4,500,000	90.	1.43
	1918	65,000	6,175,000	95.	1.35
	1919	58,000	4,930,000	85.	1.63
Average		48,400	4,397,000	90.8	
Tennessee	1915	36,000	3,168,000	88.	.63
	1916	36,000	2,952,000	82.	1.49
	1917	52,000	4,888,000	94.	1.26
	1918	50,000	3,500,000	70.	1.65
	1919	48,000	3,120,000	65.	1.72
Average		44,400	3,525,600	79.4	
Massachusetts	1915	26,000	3,120,000	120.	.94
	1916	25,000	2,275,000	91.	1.75
	1917	38,000	4,370,000	115.	1.75
	1918	34,000	4,522,000	133.	1.70
	1919	33,000	2,970,000	90.	1.90
Average		31,200	3,451,400	110.6	
Wyoming	1915	17,000	2,550,000	150.	.60
	1916	18,000	2,340,000	130.	1.28
	1917	32,000	4,960,000	155.	1.04
	1918	30,000	4,500,000	150.	.85
	1919	33,000	2,640,000	80.	1.90
Average		26,000	3,398,000	130.7	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Utah	1915 1916 1917 1918 1919	20,000 20,000 23,000 20,000 17,000	2,500,000 3,600,000 4,347,000 3,600,000 2,397,000	125. 180. 189. 180. 141.	$ .63 1.30 .78 .97 1.37
Average		20,000	3,288,800	164.4	
Vermont	1915 1916 1917 1918 1919	24,000 23,600 30,000 28,000 25,000	2,592,000 2,576,000 3,000,000 3,640,000 3,125,000	108. 112. 100. 130. 125.	.81 1.39 1.40 1.38 1.57
Average		26,000	2,986,600	114.9	
Alabama	1915 1916 1917 1918 1919	20,000 20,000 41,000 60,000 44,000	1,600,000 1,800,000 2,952,000 4,800,000 3,520,000	80. 90. 72. 80. 80.	.90 1.69 1.82 1.81 2.15
Average		37,000	2,934,400	79.3	
Texas	1915 1916 1917 1918 1919	42,000 40,000 46,000 60,000 52,000	2,730,000 2,000,000 2,760,000 3,300,000 3,796,000	65. 50. 60. 55. 73.	1.05 1.90 2.10 2.00 2.10
Average		48,000	2,917,200	60.8	
Arkansas	1915 1916 1917 1918 1919	28,000 25,000 46,000 48,000 41,000	2,520,000 1,625,000 3,680,000 2,400,000 3,321,000	90. 65. 80. 50. 81.	.76 1.90 1.57 1.84 2.05
Average		37,600	2,709,200	72.1	
Oklahoma	1915 1916 1917 1918 1919	35,000 34,000 36,000 50,000 44,000	2,975,000 1,802,000 2,484,000 1,700,000 3,520,000	85. 53. 69. 34. 80.	.84 1.95 1.80 1.95 2.05
Average		39,800	2,496,200	62.7	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Connecticut	1915	24,000	2,280,000	95.	$ .96
	1916	22,000	2,090,000	95.	1.75
	1917	27,000	2,970,000	110.	1.64
	1918	25,000	2,375,000	95.	1.65
	1919	24,000	1,680,000	70.	1.95
Average		24,400	2,279,000	93.4	
New Hampshire	1915	16,000	1,520,000	95.	.95
	1916	15,000	1,800,000	120.	1.66
	1917	22,000	2,354,000	107.	1.67
	1918	21,000	2,940,000	140.	1.45
	1919	20,000	2,400,000	120.	1.75
Average		18,800	2,202,800	117.2	
Louisiana	1915	28,000	1,428,000	51.	.95
	1916	25,000	1,625,000	65.	1.67
	1917	25,000	1,600,000	64.	1.84
	1918	55,000	4,345,000	79.	1.50
	1919	25,000	1,600,000	64.	2.20
Average		31,600	2,119,600	67.1	
Nevada	1915	13,000	2,236,000	172.	.70
	1916	14,000	2,660,000	190.	1.30
	1917	11,000	2,277,000	207.	1.20
	1918	9,000	1,539,000	171.	1.23
	1919	6,000	900,000	150.	1.50
Average		10,600	1,922,400	181.4	
Florida	1915	12,000	960,000	80.	1.15
	1916	15,000	1,110,000	74.	2.00
	1917	25,000	2,275,000	91.	2.05
	1918	35,000	3,500,000	100.	2.00
	1919	24,000	1,824,000	76.	2.10
Average		22,200	1,933,800	87.1	
South Carolina	1915	11,000	880,000	80.	1.15
	1916	10,000	750,000	75.	1.75
	1917	20,000	1,920,000	96.	2.10
	1918	28,000	2,856,000	102.	1.93
	1919	27,000	2,295,000	85.	2.00
Average		19,200	1,740,200	90.6	

State	Year	Acres	Total bushels	Average bu. per acre	Farm price per bu. Dec. 1
Georgia	1915	16,000	1,040,000	65.	$ .99
	1916	15,000	900,000	60.	1.75
	1917	19,000	1,596,000	84.	1.95
	1918	23,000	1,610,000	70.	1.85
	1919	23,000	1,610,000	70.	2.17
Average		19,200	1,351,200	70.4	
Mississippi	1915	13,000	1,170,000	90.	.84
	1916	12,000	780,000	65.	1.60
	1917	15,000	1,170,000	78.	1.68
	1918	20,000	1,600,000	80.	1.65
	1919	18,000	1,530,000	85.	1.85
Average		15,600	1,250,000	80.	
Delaware	1915	11,000	1,045,000	95.	.75
	1916	10,000	900,000	90.	1.25
	1917	13,000	1,235,000	95.	1.30
	1918	12,000	1,044,000	87.	1.40
	1919	11,000	913,000	83.	1.25
Average		11,400	1,027,400	90.1	
New Mexico	1915	8,000	800,000	100.	.95
	1916	8,000	816,000	102.	1.75
	1917	11,000	1,276,000	116.	1.65
	1918	10,000	1,000,000	100.	1.60
	1919	11,000	495,000	45.	1.90
Average		9,600	877,400	91.4	
Rhode Island	1915	5,000	550,000	110.	.92
	1916	5,000	370,000	74.	1.85
	1917	5,000	675,000	135.	1.75
	1918	5,000	650,000	130.	1.73
	1919	5,000	425,000	85.	1.80
Average		5,000	534,000	106.8	
Arizona	1915	1,000	95,000	95.	1.00
	1916	1,000	115,000	115.	1.80
	1917	4,000	420,000	105.	1.50
	1918	5,000	425,000	85.	2.05
	1919	5,000	350,000	70.	1.95
Average		3,200	281,000	87.8	

Canadian potato acreage; yield and price per bushel by Provinces for the years 1912-1918 inclusive.

Province	Year	Acreage	Total yield bu.	Av. bu. per acre	Av. price per bu.
	1912	33,000	6,741,000	206.4	$0.26
	1913	32,000	6,219,000	194.3	.28
	1914	32,000	6,806,000	212.7	.23
Prince Edward Island.......	1915	31,000	3,558,000	114.8	.46
	1916	31,000	6,386,000	206.0	.52
	1917	35,000	6,125,000	175.0	.75
	1918	31,543	5,362,300	170.0	.63
	1912	32,000	9,447,000	298.6	.47
	1913	32,000	5,369,000	167.8	.52
	1914	32,500	7,165,000	220.5	.49
Nova Scotia...............	1915	34,000	4,759,000	141.2	.58
	1916	34,000	6,935,000	201.0	.69
	1917	41,000	7,173,000	175.0	.92
	1918	51,250	9,942,500	194.0	.93
	1912	43,000	7,558,000	174.6	.42
	1913	43,500	10,629,000	244.4	.44
	1914	43,900	10,534,000	239.9	.40
New Brunswick............	1915	40,000	5,772,000	144.3	.64
	1916	39,000	7,488,000	192.0	.84
	1917	46,000	6,891,000	149.8	1.13
	1918	57,272	9,077,600	158.5	1.00
	1912	116,000	15,945,000	137.1	.35
	1913	116,000	20,504,000	176.8	.46
	1914	115,000	21,811,000	189.7	.42
Quebec....................	1915	117,000	17,510,000	149.7	.55
	1916	112,000	14,672,000	131.0	.97
	1917	226,917	18,158,000	80.0	1.38
	1918	264,871	38,936,000	147.0	.98
	1912	158,000	22,690,000	143.9	.59
	1913	152,000	18,105,000	119.1	.65
	1914	154,000	25,772,000	167.4	.47
Ontario...................	1915	155,000	14,362,000	92.7	.76
	1916	133,000	8,113,000	61.0	1.28
	1917	142,000	18,981,000	133.8	1.00
	1918	166,203	20,443,000	123.0	1.26
	1912	27,000	6,182,000	231.6	.35
	1913	26,000	5,120,000	196.9	.36
	1914	26,900	3,172,000	117.9	.72
Manitoba..................	1915	28,000	3,104,000	109.7	.54
	1916	32,000	4,709,000	170.0	.61
	1917	34,400	3,643,000	106.0	.76
	1918	45,000	8,325,000	185.0	.56

Province	Year	Acreage	Total yield bu.	Av. bu. per acre	Av. price per bu.
Saskatchewan	1912	31,000	6,552,000	209.7	$ .40
	1913	31,000	5,138,000	165.7	.47
	1914	30,600	4,085,000	133.5	1.05
	1915	30,300	4,428,000	146.2	.49
	1916	47,000	7,319,000	176.0	.62
	1917	67,700	9,010,000	133.0	.85
	1918	59,793	6,950,900	116.3	.96
Alberta	1912	27,000	5,775,000	211.6	.39
	1913	26,000	4,350,000	167.3	.39
	1914	26,300	3,652,000	138.9	.65
	1915	27,300	5,155,000	188.8	.33
	1916	29,000	4,783,000	177.0	.53
	1917	48,917	7,409,000	151.5	.76
	1918	44,247	3,119,400	70.5	1.11
British Columbia	1912	17,000	3,995,000	233.2	.49
	1913	15,000	3,110,000	207.3	.66
	1914	14,700	2,675,000	182.0	.78
	1915	16,000	3,956,000	247.3	.45
	1916	15,000	2,892,000	189.0	.70
	1917	15,024	2,502,000	166.5	.69
	1918	15,013	3,423,000	228.0	.97

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[1] The numbers in **Black** refer to the group to which they belong.

*Not the true Bresee's No. 6.