THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Examination

This is to certify that we the undersigned, as a committee of the Graduate School, have given **Fred Alfred Krantz** final oral examination for the degree of Master of **Science**. We recommend that the degree of Master of **Science** be conferred upon the candidate.

Minneapolis, Minnesota

May 31 1911

W. A. Alderman
Chairman

L. I. Knight

M. J. Dorsey.

THE UNIVERSITY OF MINNESOTA

GRADUATE SCHOOL

Report

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Fred Alfred Krantz for the degree of Master of Science. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science.

W. H. Alderman
Chairman

L. L. Knight

M. J. Dorsey.

May 31 1921

A STUDY OF THE PERMANENCE OF THE VARIETY IN THE POTATO

A Thesis Submitted to the Faculty of the
Graduate School of the University of Minnesota

by

Fred. A. Krantz

In Partial Fulfillment of the Requirements
For the Degree of
Master of Science

June

1921.

A STUDY OF THE PERMANENCE OF THE VARIETY IN THE POTATO

by

Fred A. Krantz

OUTLINE

INTRODUCTION

REVIEW OF LITERATURE

METHODS AND MATERIALS

THE EFFECT OF SELECTION AND ENVIRONMENT ON THE POTATO PLANT

- Effect on Productivity of Lots
- Effect on Form of Tuber
- Effect on other Tuber Characters

CONCLUSION

SUMMARY

BIBLIOGRAPHY

A STUDY OF THE PERMANENCE OF THE VARIETY IN THE POTATO*

The practice of selection within the clone to maintain and improve the productivity and quality of potato varieties is of comparatively recent origin. In the early period of potato improvement, hybridization with subsequent selection of the most promising seedlings was the method employed. The practice of vegetative selection is founded for the most part on the success of numerous attempts to isolate high and low yielding strains. Many investigators consider that the greatest benefit to be derived from selection is the maintenance of the optimum vigor of the variety, while other investigators believe that the results indicate the presence of inherited differences within the variety and have therefore considered selection to be of value in the improvement of varieties. Recent advances in the knowledge of certain diseases hitherto unrecognized has thrown considerable doubt upon the correctness of the latter interpretation. This study has for its primary object a determination of the effect of selection upon the variety as practiced by growers and a determination of the stability of regional differences, when the disease factor is eliminated.

---

* The experiment was originated by A. W. Aamodt who collected the original lots of potatoes, took descriptive data on them and who supervised the planting in the spring of 1917. The work was carried on under the supervision of Richard Wellington from the time of its inception until the spring of 1919. Thanks are also due O. I. Berg of the North Central Station, Grand Rapids, Minnesota; Mark Thompson of the North East Station, Duluth, Minnesota and Thos. McCall of the North West Station, Crookston, Minnesota for their cooperation at the substations.

10-20 5M

REVIEW OF LITERATURE

The older theory suggested by Knight (31) and Aitkin (1) of varietal senility has given place to that of the deterioration of seed stock. Since selection has for one of its primary objects the prevention of this deterioration, a brief historical review of these theories will be of interest.

As early as 1787 William Marshall (35) writing from England, reported that potato varieties were transitory in each district. He noted that the declining varieties were characterized by curled tops. Cathcart (6) quotes Stephen's Book of the Farm as authority for the statement that the condition of curl was first observed in 1764. Marshall considered curl to be due to varietal senility as it was noted that new varieties secured from seed were not subject to this condition. The following statement by Knight (30) in 1807 indicates the transitory nature of potato varieties at that time. "Dr. Hunter, in his Georgical Essays, I think, has limited the duration of a variety, in a state of perfection to about fourteen years; and probably taking varieties in the aggregate, and as the plant is generally cultivated, he is nearly accurate." In a previous publication (31) Knight had put forward the theory of varietal senility, although he did not lay special emphasis on the potato. His hypothesis was that all plants propagated vegetatively, have their period of maximum vigor when at middle age and then become "subject within no very distant period to the debilities and diseases of old age." Aitkin (1) applied the hypothesis to potatoes in 1837 and it was accepted by

10-20 5M

many later writers. Ehrenburg (11) in 1904 after reviewing the work of previous investigators concluded that the idea of varietal senility was untenable. East (9) in 1908 came to a similar conclusion and notes "that the people who have considered this single question are unanimous in opposition to the hypothesis of varietal senility."

Ehrenburg considered that the hypothesis of the deterioration of seed stocks being due to unfavorable environment had some basis for its support. East regarded disease to be the most important factor to be considered in connection with the degeneracy or running out of seed stocks. Orton (39) in 1914 called attention to the so called degenerative diseases of "mosaic", "curly dwarf" and "leaf roll" and to the probable role these diseases played in the running out of seed stocks. The general distribution and harmful effect of these diseases on the vigor of the plant, which has been brought out by later investigators Stewart (51), Appel (2), Melhus (36), Murphy (37), Gussow (26), Wortley (60), Shultz, Folson, Hildebrandt and Hawkins (49) Quanger (42), Shultz and Folsom (50), has made it increasingly clear that the so called running out of seed stock is probably nothing more than a manifestation of these diseases.

Very little attention was paid to the possibility of improving varieties by means of asexual selection previous to the latter half of the ninteenth century. It has apparently never been considered worthy of serious attention by investigators in the British Isles. Sutton (53) in 1898, Wilson (61) in 1907 in their discussion on the improvement of potatoes have

expressed their belief that the seedling was a finished product and that further selection was of no value in its improvement. On the continent and in the United States and Canada numerous investigators have attempted to ascertain its value. The meagreness of details in most of the earlier published reports on selection experiments makes them of little value in determining the place that selection occupies in the improvement of the potato. The most important papers on the value of selection have been reviewed by East (9) in 1908 and more recently by Stuart (52) in 1915. East after reviewing the work of Hellriegel (29) Franc (17) Emery (13) Wollny (63-64) Marek (33) Girard (23), Wholtmann (62) Thiele (54) Goff (24, 25), Bolly (3) Fruwirth (18, 19, 20, 21) Remy (43, 44), Fischer (14, 15, 16), Paulson (41), Martinet (34), Hess (28), Bruner (5) Sempolowski (48) Von Seelhorst (45, 46, 47) Krzymowski (32) Eustace (12) and Parisot (40), pointed out that the evidence was inconclusive and called attention to the influences which tended to obscure the results obtained by these investigators. Waid (55) in 1907 at the Annual Meeting of the American Breeders Association reported the results of studies on hill selection of seed potatoes. The results showed quite clearly that the progeny of low yielding hills remained unproductive in comparison to the progeny of high yielding hills. The favorable results reported in this work caused considerable emphasis to be placed on this method, of improvement. The following year Webber (56) put forward a method of selection, known as the tuber unit method, which has received considerable attention. East (10) in 1910 suggested that Waid's re-

sults might have been influenced by the size of the seed piece used and the fact that Waid might not have been dealing with a pure strain as he apparently used a commercial stock. East found no difference in yielding between the progeny of high and low yielding hills in stock which was obtained from a single tuber of the Rural New Yorker Variety. He believes "that great caution should be exercised in recommending asexual selection to commercial growers as a means of actual improvement of the crop, in view of the facts, first that of many investigations on the point no indisputable evidence of improvement has been reported and second, that even the questionable instances of positive results are extremely rare."

Stuart (52) reported in 1915 the results obtained in some rather extensive studies on the value of the tuber-unit and hill selection methods as means of potato improvement. A remarkable dissimilarity between individual units and between individual hill selections was obtained. Stuart did not attempt to explain the cause of the differences obtained further than to point out that in certain instances "other causes than that of inherent unproductiveness must have oper ated to lower the yield," and states "that the tuber unit-method and hill selection method of improvement are chiefly valuable in pointing out the weak, unproductive, and diseased tubers.

Stewart (51) in his observations on some degenerate strains of potatoes states that "it is doubtful if any method of seed selection will prevent the "running out" of seed potatoes under certain conditions." In a recent article Whipple (56) has published the results of five years work in pure line selection.

10-20 5M

He calls attention to the persistency with which degenerate types (curly dwarf) appear in pure lines and the consequent difficulty of interpreting yield data. Similar experiences had been recorded by Wellington (57) in a paper in which he points out the uselessness of hill selection under conditions where rapid deterioration or running out is prevalent. The deterioration mentioned by Wellington was expressed by the production of the so-called "curly dwarf" type of plants, which recently has been found by the writer, to be very similar in its nature to mosaic and is probably nothing more than a severe expression of this disease. A few experiments have been conducted to test the effect of asexual selection on characters other than that of yield. The results of a carefully conducted experiment to determine the effect of selection for high and low nitrogen content was reported by East (10) in 1910. No difference in nitrogen content was found during three years of continuous selection. In conclusion East states "that neither the relative content of dry matter nor that of nitrogenous matters of the potato can be changed by the selection of fluctuations." In attempting to isolate a blight resistant strain of potatoes Stuart (52) obtained indifferent results. After selecting for three years to improve the form and increase the yield of the White McCormick variety, White (59) concluded that no improvement could be secured in this variety through selection. As previously mentioned Stewart (51) and Wellington (57) were unsuccessful in trying to isolate a strain of potatoes resistant to the factors causing degeneracy.

The evidence presented does not offer much encouragement to the use of asexual selection by the plant breeder in improving the potato. The opportunity that the mechanism of sexual reporduction offers for the segregation and recombining of characters makes the method of hybridization with the subsequent selection of seedlings a more promising method for potato improvement. It has frequently been assumed that sufficient variation existed in all varieties to justify the grower in attempting improvement by asexual selection.

METHODS AND MATERIALS

In the fall of 1917 six lots of Early Ohio potatoes were secured from growers in different parts of Minnesota. Five of the lots were from growers who had practiced little or no selection. The sixth was from a grower who had practiced continuous mass selection of tubers for vigor and type in the same seed stock over a period of approximately twenty years. In 1919 a seventh lot of Early Ohios was obtained from a grower who had practiced continuous mass selection of tubers for vigor and type in the same seed stock over a period of twenty one years. The two growers differed in their ideas of what constituted the ideal type of the Early Ohio variety and had selected toward divergent types. Attention is called here to the fact that these two seed stocks were known to be separated from each other and from the lots other for twenty years. This would seem to allow ample time for strains to develop within the seed stocks if there was a tendency for this condition to occur. The various lots represented distinct regional types found with-

the state. While it was recognized as a possibility that these seed stocks might not be asexual progeny of the same variety it was still considered that a study of them would be of interest in determining the value of selection as practiced by the growers.

THE EFFECT OF SELECTION AND ENVIRONMENT ON THE POTATO PLANT

Effect on Productivity of Lots: Before discussing the productivity of the different seed stocks in 1917, attention should be called to the source, from which they were obtained in 1916. This is given in Table I. The exact number of years that the seed stock was grown at the places from which they were obtained is not definitely known, further than that lot 2 and 9 were grown at the places indicated for over twenty years. Lot 9 it will be noted was not obtained until 1919. The yield in 1917 of the six lots obtained in 1916 is shown in Table I, column III. The yields given were secured from a four rod row calculated to bushels per acre. It will be noted that in 1917, no lot gave consistently the highest yield at more than two places, no lot gave consistently the lowest yield at more than two places. Lot 6 gave the highest yield at University farm and Duluth. Lot 2 gave the lowest yield at University Farm and Crookston. At Grand Rapids, however, Lot 2 yielded 12 bushels more per acre than lot 6.

In 1918 the portions of the lots grown at Duluth, Grand Rapids and Crookston were again grown at the following places. Lots 6 and 7 were grown at University Farm, Grand Rapids and Crookston; lot 2 at University Farm, Grand Rapids and Crookston. Before comparying the yield of the different lots for 1918 it might be will to call attention to the fact that the dif-

Table I. Showing productivity of Early Ohio lots at University Farm, Duluth, Grand Rapids and Crookston in 1917, 1918, 1919 and 1920.

I Lot	II Source of Seed 1916	III Yield in 1917 at				IV Yield in 1918 of seed grown at Duluth in 1917				V Ave. Yield of Duluth seed grown at all places
		U	D	G	C	U	D	G	C	
2	Anoka	205	203	326	44	293	193	290		259
3	Grand Rapids	183	174	318	63	242			249	246
4	Faribault	216	174	311	80	278	220			240
6	Duluth	269	219	314	75	297	165	246	301	251
7	Glyndon	261	202	316	71	346	152	256	273	232
8	Hawley	259	179	265	56	264		314	258	279
Average		232	192	308	65	287	182	277	270	251

Table I continued

VI Lot	VII Yield in 1918 of seed grown at Grand Rapids in 1917				VIII Aver. Yield of Grand Rapids seed at all places	IX Yield in 1918 of seed grown at Crookston in 1917				X Aver. Yield of Crookston seed at all places	XI Aver. yield of all seed stocks, of each lot, grown in 1918.			
	U	D	G	C		U	D	G	C		U	D	G	C
2	271	138	299		237	202	143	269		205	255	158	286	
3	224			220	222	263			249	256	243			240
4	224	110			207	315	146			231	272	185		
6	293	158	247	249	262	308	169	311	255	261	299	164	266	268
7	227	178	266	155	207	271	139	359	296	267	248	156	297	241
8	218		255	191	211	288		256	235	299	258		298	228
Ave.	243	146	259	204	224	274	149	299	259	247				

Table I Continued.

Lot	XII Summary of yield of each lot at all places in 1917	XIII Summary of average yield in 1918					XIV Summary of average yield in 1919		XV Yield in 1920 at Grand Rapids
		UDGC	UDG	UGC	UD	UC	UDG	UG	
2	195		233		207		258	584	150
3	200					241			
4	196				229				
6	215	249	243	278	232	284		254	
7	202	236	233	262	202	245	201	203	130
8	207			261		243		234	
9	Hopkins (obtained in 1919)								147

10-20 5M

ference in growth conditions of the various portions of each lot in 1917 had apparently no influence on their yield in 1918. See Table I columns III to IX inclusive. In the lower line of the columns noted is given the average of all yields for each place in 1917 and 1918. The average yield of the six lots at Crookston in 1917 was 65 bushels per acre, at Duluth 192 bushels, and at Grand Rapids 308 bushels per acre. The average yield in 1918 at University Farm, Duluth, Grand Rapids and Crookston of the portions of the six lots grown at Crookston in 1917, was 247, of the portions of the six lots grown at Grand Rapids in 1917, was 224, of the portions of the six lots grown at Duluth in 1917, was 251. The low yield of all lots at Crookston in 1917 was due to excessive rainfall and an early frost. These factors which affected the yield and also the appearance of the tubers to such an extent as to make them appear worthless for seed stock had apparently no influence on their yielding ability.

The yield of the seed stocks in 1918 were no more variable than those obtained in 1917. In column XI table I is given the yield of each lot at each place where it was grown. Lot 6 gave the highest yield at two of the four places, at University Farm and crookston, It gave the lowest yield of all lots grown at Grand Rapids. There was no lot gave the lowest yield at more than one place. The results show that the variations are due to other causes than differences in yielding ability. This conclusion is further supported by the results obtained when the average yields of the lots for all places are compared. See table I columns XII to XIV inclusive.

10-20 5M

The range of variation in yield between the lots in 1917 was twenty bushels. The lots do not group themselves into high or low yielders but are quite uniformly distributed within this range. The yields of the lots in 1918 approach each other very closely. Lots 6 and 4 have a slight advantage in yield. Lot 4, however, gave a low yield in 1917. Lot 6 was outyielded in 1919 by lot 2. Lot 2, as has been pointed out above was the lowest yielding stock in 1917. A seventh lot designated as lot 9 was obtained in 1920. When grown at Grand Rapids in 1920 in comparison with lot 2 and 7, it gave a greater yield than lot 7 and slightly less than lot 2. The seed stocks in which selection had been practiced was 2 and 9. The fact that neither a large nor a consistent difference in yield was obtained from the different seed stocks would indicate that a significant difference probably did not exist. It is quite evident that the selected seed stocks 2 and 9 were not superior in vigor to the unselected seed stocks.

Effect on Form of Tuber: Of the various tuber characters that are usually collectively designated as type, that of form is one of the most important. Representative tubers of the original seed stocks are shown in figures 1, 2, 3, 4, 5, and 6. Lot 2, obtained from Anoka, Minnesota was oval in shape being short and broad. (See figure 1). Continuous selection had been practiced by the grower towards this form of tuber. It is only fair to state that this form is also representative of the sandy loam soil of the region in which it was grown. Lot 3 was obtained from the North Central Experiment Station. As shown in Figure 2 the tubers of this lot are relatively long

and narrow. The Early Ohio potatoes produced at this station since that time, i.e. in 1917, 1918,1919 and 1920 have been relatively short and wide. Lot 4 was obtained from Faribault, Minnesota. The tubers of this lot were quite elongated and were apparently somewhat variable in form. See figure 3. It contained a few tubers that tended toward an oval form. Lot 6 was obtained from the region about Duluth. The tubers of this lot were longer, broader and more flattened than those of lot 2. Lots 7 and 8 were obtained from growers in the Red River Valley. The tubers of these lots were characteristic of the more elongated cylindrical form of the Early Ohio of this region. A portion of each of these lots was grown at University Farm, Duluth, Grand Rapids and Crookston in 1917. The form of the tubers produced at each of these places was very similar in all the lots. It was evident that regardless of the form of the tubers in the original lots that the growth conditions at each place produced a uniform distinctive form of tuber. The 1917 crop was carefully studied for possible differences in form between the lots grown at any one place. It was thought that slight differences in form were observable between some of the lots grown at Duluth. These differences inform were not found to remain consistently in 1918, although a similar amount of variation between the lots was observable.

DeVries (8) in a study of the development of the potato tuber states that the form of tuber is determined by the rate of length growth as compared to its width growth. Correlation studies for the ratio of width to length of tuber are

presented in tables III to IV inclusive. The coefficients are here sumarized.

Table II. Summary showing the relation between width and length of tubers in the Early Ohio Variety.

Year	Variety	Place Grown	Coefficient of Correlation	$\frac{r}{er}$	Number of individuals
1919	Early Ohio	Grand Rapids	.718±.014	51.2	571
"	"	Duluth	.847±.010	84.7	310
"	"	U. Farm Clay loam	.647±.032	20.0	148
"	"	U. Farm Sandy loam	.601±.030	20.0	161

The data presented in these tables show that there is a decided correlation between the width and the length of tuber is quite similar for both small and large tubers of the same lots. The ratio of width to length of tuber would therefore appear to be a very good index of form in the Early Ohio variety. In 1919 the tubers of lots 2, 6, 7, and 8 were measured and the mean ratio of width to length obtained. The results are shown in Table VII.

Table III Correlation between width of tuber and length of tuber in the Early Ohio Variety grown at the North Central Experiment Station, Grand Rapids, Minnesota.

Coefficient of Correlation .717±.041

Length of tubers in millimeters

Width of tubers in millimeters	46	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114	118	122	126	130	
40				1																			1
42		1																					1
44			2			1	1		1														5
46		1	1	10	2	1	1	2		1													19
48			1	9	7	5	2	1	1														26
50		1	4	7	10	9	8	3		1	1												44
52			3	7	15	12	14	2	5	2	1												61
54			1	2	9	17	14	7	6	9	2	1											68
56		1		3	4	7	12	9	9		3	2	1	1	1								53
58				1		3	14	14	15	11	6	5	4		2								75
60		1		1		5	10	7	12	10	8	8	2	2	1								67
62				1	1	2	1	7	4	7	6	4	3	3	3		1	2					45
64							3		5	5	4	2	1	1	4	1	2						28
66						2		2		1	2	1	6	2	1	1							18
68						1	1	1		1	4	2	3	1	2		3	1					19
70										2	1	3	2	2	2			2	1	1			16
72												2	1	2	1	1	0		1	0		1	9
74							1			1		1			2								5
76													1		1		1		1				4
78														1									1
80												1					1						2
82													1					1	1				3
84																							1
		5	12	42	48	64	82	55	58	50	38	32	26	15	20	3	8	6	4	1		1	571

Table IV Correlation between width of tuber and length of tuber in the Early Ohio Variety grown at North East Experiment Station, Duluth, Minnesota in 1919.

Coefficient of correlation .847±.010

Length of tubers in millimeters.

Width of tuber in millimeters	46	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114	118	122	126	130	
44		1																					1
46		1	2		2	1																	6
48	1	5	5	6	1																		18
50		4	7	4	2	1	2																20
52	2	1	1	9	6	2	3																24
54			6	5	14	4	2	1															32
56			2	7	1	13	7	2				1											33
58				5	8	7	6	4															30
60				1	5	7	6	4	2			1											26
62				2	2	6	3	6	3	2	2												26
64					2	5	3	6	2	2	2												22
66					2	2	1	7	1	3	2												18
68				1		1	1	4	3	2	2	1	1	1									17
70						1	1		1	4													7
72							1				4	1		1	2								9
74									1	3	1	3	1			1							10
76											1	1	1										3
78												1					1						2
80																							
82														1			1						2
84																							
86															1			1					2
88														1									1
90																1							1
92																							1
	3	12	23	40	45	50	36	34	13	16	14	9	5	4	3	2	2	1					310

Table V Correlation between width of tuber and length of tuber in the Early Ohio Variety grown on clay loam soil, at Central Experiment Station, University Farm, St. Paul, Minnesota in 1919.

Coefficient of correlation .647±.032

Length of tubers in millimeters.

Width of tubers in millimeters	46	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114	118	122	126	130	134	
42																								
44				1	1		1																	3
46				1	1	1	2	1	2															8
48					2	4	4	1	1	1														13
50			1	1	1	1	2	1		3														10
52				1		2	1	2	2		3	3	1											15
54				1	2	2			5	3	1	1	1											16
56				1				4		4	1	1	1											12
58			1					2	1	5	3	4		1	2	1								20
60										3	1	3			2									9
62					1				2	1	1	3	1			1	1							11
64									2	1	1	2	2			1	1	1						11
66							1					1		2	2			1						7
68											2			1										3
70											1	1		1										3
72										1														1
74														2										2
76														1										2
78													1											1
80																								
82																								
84													1											1
			2	6	8	10	11	11	15	22	14	19	8	8	6	3	2	2						148

Table VI. Correlation between width of tuber and length of tuber in the Early Ohio variety grown on sandy loam soil at Central Experiment Station, University Farm, St. Paul, Minnesota in 1919.

Coefficient of correlation .601±.034

Length of tubers in millimeters

Width of tuber in millimeters	46	50	54	58	62	66	70	74	78	82	86	90	94	98	102	106	110	114	118	122	126	130	134	
42	1					1		1																3
44						5	1	2			1													9
46					1		5	2	1	1	1	1												12
48					1	1	1	5	2	3	1		1											15
50						1	3	3	1	3	5		1											17
52							1	1	3	2	4	2	3	2										18
54				2				1		1	2	1	2	1										10
56								1	1	1	3	1	1	2	1	2	1							14
58							2	1		1	1	1	3	3	1	3		1	1					18
60									1		1	2			2	1								7
62												1		3	2	1	2	1						10
64										1	1					2		1						5
66												1	1			1		2			2		1	8
68																1		2						3
70													1					1	2		1			5
72																	1		1					2
74																		2						2
76														1										1
78																								
80																							1	1
82																								
84																						1		1
	1			2	2	8	13	17	9	13	20	10	13	12	6	11	4	10	4		3	1	2	161

Table VII Frequency table showing the amount of variation in form between different lots of Early Ohio potatoes in 1919.

Lot	Place Grown	Index of width to length classes .90	1.10	1.30	1.50	1.70	1.90	Total	Mean
2	Grand Rapids		22	67	39	12	1	141	1.36±.01
6	"	2	58	103	59	7		229	1.31±.01
7	"		15	67	30	11	1	124	1.36±.01
8	"	1	28	69	37	4	1	140	1.33±.01
2	Duluth	14	110	38	2	1		165	1.14±.01
7	"	12	83	83	9		1	188	1.20±.01

The mean of lots 2, 6, 7 and 8 grown at Grand Rapids ranges from 1.31 to 1.36±.01. The mean oflots 2 and 7 grown at Duluth was 1.14±.01 to 1.20±.01 respectively. The difference between themeans of the lots grown at Duluth would appear to be significant. The difference, however, is small as compared to that between portions of the same lot grown at different places, furthermore a similar difference was not obtained between lots 2 and 7 at Grand Rapids, where the mean for both lots was 1.36 ±.01.

The influence of growth conditions on the form of tubers is of interest. In table VIII the mean of tubers of lot 2 as grown at different places are given.

10-20 5M

Table VIII Frequency table showing the effect of different growth conditions on the form of the Early Ohio tuber.

Lot	Place Grown	Index of width to length classes .90	1.10	1.30	1.50	1.70	1.90	2.10	total	Mean
2	Grand Rapids		22	67	39	12	1		141	1.36±.01
2	Duluth	14	110	38	2	1			165	1.14±.01
2	U.Farm Sandy Loam		1	3	17	25	13	1	60	1.65±.02
2	U.Farm Sandy Loam		13	17	30	44	10	1	105	1.59±.01
2	U. Farm Clay Loam	1	13	39	64	28	2		147	1.45±.01

The tubers of this stock when grown at Duluth were short broad and quite flat having a mean ratio of width to length of 1: 1.14. An illustration of this form of tuber may be seen in figure 4 which shows the original form of lot 6 as grown at Duluth in 1916. At University Farm on sandy loam soil the tubers were elongated, more or less cylindrical having a mean ratio of width to length of 1: 1.65. At Grand Rapids the tubers tended somewhat toward the form of those grown at Duluth but were less flattened and were more elongated in relation to their width, the mean ratio of width to length being 1: 1.36. On clay loam soil at University Farm the tubers were similar to those in the sand in being more or less cylindrical but were relatively greater in thickness and breadth and shorter, having a ratio of 1 to 1.44. The effect of seasonal conditions on form of tuber is shown in Table IX.

Table IX Frequency table showing effect of seasonal conditions of the form of the Early Ohio tuber.

Lot	Year	Ratio of width to length classes .90	1.10	1.30	1.50	1.70	1.90	total	Mean
2	1919		22	67	39	12	1	141	1.36±.01
7	1919		15	67	30	11	1	124	1.36±.01
2	1920	1	28	38	4			71	1.23±.01
7	1920	1	14	30	1			45	1.23±.01

Lot 2 and 7 were grown at Grand Rapids in 1919 and 1920. Tje tubers in 1919 were longer in comparison to their width than in 1920, having a ratio of width to length of 1 to 1.36 in 1919 and 1 to 1.23 in 1920.

In 1920 lot 9 was obtained from a grower who had selected for a somewhat more elongated form of Early Ohio. The lot as obtained in the fall of 1919 gave a mean of 1.566±.02. When grown at Grand Rapids in 1920 in comparison with lot 2 and 7, no difference in form between these various lots was obtained, as can be seen b y a study of table X.

Table X. Frequency table showing the amount of variation in form between different lots of Early Ohio potatoes in 1920.

Lot	Place Grown	Ratio of width to length classes .90	1.10	1.30	1.50	1.70	1.90	Total	Mean
9	Hopkins (1919)		1	2	15	10	2	30	1.60±.02
9	Grand Rapids	3	32	40	9			84	1.23±.01
2	" "	1	28	38	4			71	1.23;.01
7	" "	1	14	30	1			45	1.23±.01

The mean index of the three lots is 1.23±.01. The mass selection practiced by the grower in lot 9 for twenty one years had no effect on the inheritable form of the Early Ohio tuber.

Effect of Environment on Other Characters: The formation of knobs is an undesirable character. This fact has been so obvious to potato breeders that the expression of this character by seedlings resulted in their rejection, so that our commercial varieties do not form knobs when growth conditions are uniformily favorable throughout the season. When growth conditions are such as to cause a second growth of the plant, the formation of knobs frequently occurs on the tubers of some varieties. In the original lots of Early Ohio secured in spring of 1917 all were comparatively free of knobs except lot 8. All but lot 2 had traces of knobs formed. The progeny of these lots when examined in the fall of 1917 were found to be similar for this character in all lots grown at the same place. Knobs were present to a greater or lesser degree on the tubers of the lots grown at Grand Rapids, University Farm and Crookston, those at Duluth were free of knobs. In 1918 all lots produced knobs, at the University Farm, while at Duluth, Grand Rapids and Crookston potatoes were free of knobs. The six lots appeared to give a similar reaction in regard to the formation of knobs under similar environmental conditions.

Another undesirable character is the formation of fissures or crevices on the surface of the tubers. The tubers of the original lots of Early Ohio were free of these

2.20.8m

fissures. Tubers containing these fissures were frequently found in all the lots grown at University Farm in 1917 and 1918. In 1917 they were occasionally found in tubers of lots grown At Crookston. At no time were fissures found in tubers of lots grown at Duluth and Grand Rapids.

The depth of eyes and prominence of eye brows were found to be similar for the progeny of all lots grown at the same place. Distinct differences in the expression of these characters were produced at the different places but this difference in expression had no influence on the progeny since the characters were again expressed according to the environmental conditions under which the tubers developed.

The surface of the skin of the Early Ohio tuber is covered with Samll corky dots or lenticels. DeVries (8) has shown that the lenticels on potato tubers are due to the growth of loose cells underneath the stomates, which push up thru the stomates and rupture them. He pointed out that a prominent development of them could be secured by having the tuber develop under moist conditions. These dots either do not occur at all or are relatively inconspicuous on varieties belonging to the Rose Group. The original lots differed in the number and prominence of these lenticels on their tubers. The lenticels were very prominent on the progeny of all the lots grown at University Farm in 1917, slightly less prominent on the Crookston lots, slightly prominent on the Grand Rapids lots and very inconspicuous on the Duluth lots. A similar result was obtained in 1918.

In the original seed stocks the tuber color was distinctly different for each lot. This difference did not reappear in the progeny of the lots when grown under similar conditions. The growth conditions at each place produced a characteristic color of tubers. At times there appeared to be a difference between lots grown at the same place, but no lot was consistently different from the others in this respect. There was always considerable variation present between indidual tubers of the same lot. In general the larger tubers appeared less highly colored than the smaller tubers. The color in the tuber of this variety is in the tissue directly beneath the cells forming the outer skin. DeVries (8) called attention to the fact that in the last growth of the skin during the ripening period the skin which is previously clear, transparent, and smooth becomes thick and transparentless. In the lots of Early Ohios under observation there was probably no difference in the amount of color present, but a difference of the degree to which it was masked. The vines especially at Duluth, Grand Rapids and Crookston were usually killed by frost before the ripening period was completed, so that the stage of maturity probably played quite a role in the color appearance of the tubers. The type of soil at a particular place had also a noticeable effect on the skin as for instance the tubers when grown in sandy loam soil at Grand Rapids possessed a flakiness of skin, when grown at Duluth on clay soil containing a plentiful supply of humus they were extremely smooth, a similar smoothness was obtained on tubers of the same stock when grown on peat at the Coon Creek Peat Experimental Farm, Anoka, Minne-

sota. These and other factors which influenced the texture and quality of the skin were probably the cause of the difference in color appearance of the tubers.

CONCLUSION

Bolley 3, 4, in 1897 and 1900 concluded from his observation on the Early Ohio variety that potato varieties run into definite strains. It is evident that the lots of Early Ohio reported in this study were as far as could be ascertained identical in their characteristics. The number of lots under observation was relatively small. We must, however, consider that each lot was chosen because it offered a possibility of its being a distinct strain. Furthermore two of the seed stocks were known to have been separated from each other and from the other seed stocks studied for at least twenty years, as the Early Ohio originated approximately fifty years ago, twenty years would seem to a sufficient length of time to allow strains to develop within the seed stock of a variety if such a tendency existed. The selection practiced by the growers, with divergent types in view should further have tended to bring out any differences that might have developed. Also the difference in environment was sufficiently great to bring out distinct differences in the expression of characters studied. If the environment had any tendency to influence the expression of the character in the progeny its influence should have been apparent at the end of this period. The evidence presented indicates that the potato variety is relatively stable under vegetative propagation. While mutations undoubtedly occur they are paparenly not sufficiently numerous to offer reason-

able hope of improvement by asexual selection. Caution should therefore be exercised in recommending asexual selection to the grower as a means of potato improvement. The maintenance of seed stocks of varieties is a matter of disease control. It has been a common practice to ascribe to changes in inherent factors any deterioration in seed stocks that was not accompanied by recognizable symptoms of known diseases. Whenever the causes have been ascertained they have been found to be due to disease. It is doubtful if any method of asexual selection that has been advocated for the improvement of the potato can be justified on the basis of disease control, for it would appear that those diseases which selection would tend to eliminate would be more effectually controled by the discarding of specificly diseased tubers and the rogueing out of diseased plants in the seed plot. It can therefore be stated that the evidence at the present time does not favor the practice of asexual selection either for the improvement or maintenance of potato varieties.

SUMMARY

Seven lots of Early Ohio potatoes representing different lines of selection practiced by growers and distinct regional types were obtained from growers at Anoka, Duluth, Grand Rapids, Glyndon, Hawley, Faribault and Hopkins, Minnesota. Observations were made on the behavior of the lots in 1917 when grown in comparison to each other at University Farm, Duluth, Grand Rapids and Crookston. In 1918 the lots were under observation at two or more places. On certain of the lots observations were continued in 1919 and 1920.

In 1917 there was a difference of 20 bushels per acre between the average yield at the four places of the highest and lowest yielding lot. No lot consistently gave either a high or low yield at more than two places. Lot 6, the highest yielding lot in 1917, gave the highest yield in 1918 but in 1919 it was outyielded by lot 2, the lowest yielding lot in 1917. Lot 9 obtained in 1920 gave an almost identical yield to lot 2. The selection practiced by the growers on lot 2 and 9 had apparently no effect on increasing their productivity.

The ratio of width to length to tuber was found to be a fairly good index by which differences in form could be detected, in the Early Ohio variety. It furnished a mathematical expression by whichthe form of tubers grown under different conditions and during different seasons could be compared. The progeny of all lots were similar in form when grown under similar growth conditions, a considerable difference in expression of the form of tuber occurred at different places during the same season, and at the same place during different seasons. This sensitiveness of form of tuber to differences in growth conditions may account for Bolley's conclusion, from observations on the Early Ohio variety, that potato varieties run into definite strains.

The presence of knobs, fissures, prominence of lenticels, depth of eyes, prominence of eye brows, color of tubers were characters that were found to be unexpressed, expressed or modified in their expression according to the environment under which the tubers developed. The environment under which

the tubers were produced had no influence on their progeny. The expression of these characters on the tuber was not influence by selection or by the environmental conditions surrounding the development of the seed stock. The evidence presented shows that potato varieties do not run into definite strains, that they are relatively stable under vegetative propagation, and that method of asexual selection does not offer reasonable hope for their improvement.

Bibilography

1. Aitken, W., The Potato rescued from disease, Lond. 1837.

2. Appel, O. Leaf Roll diseases of the potato, Phytopath, 5:139-148, 1915.

3. Bolley, H. L. Preliminary report upon the selection of potatoes for planting. N. Dak. Agr. Exp. Sta. Bul. 30:210-243. 1897.

4. Bolley, H. L. Notes on potato seed selection N. Dak. Agr. Exp. Sta. Ann. Rpt. 1900:39-43.

5. Brummer, J. Einfluss der Saatkartoffeln von mehr oder minder fruchtbaren Staudin auf die Kartoffelerträge. Deut. landw. Rundsch. 1891:301.

6. Cathcart, Earl On the cultivated Potato. Jour. Roy. Agr. Soc. Eng. (ser. 2) Vol. 20 p 266. 1884.

7. Carriere, E. A. Producation et Fixation des Varietes dans les Vegetaux 72 p illus. Paris, 1865.

8. De Vries, Hugo Wachsthumsgeschichte der Kartoffelpflanze Landw. Jahr. 70:591-682, 1878.

9. East, E. M. A study of the factors influencing the improvement of the Potato. Ill. Agr. Exp. Sta. Bul. 127:1908.

10. East, E. M. The transmission of variations in the potato in Asexual reproduction. Conn. Agr. Exp. Sta. 33d and 34th report, 119-160. 1910.

11. Ehrenberg, Paul Der Abbau der Kartoffeln, Landw. Jahrb. 33:859-915. 1904

12. Eustace, H. J. An experiment on the selection of seed potatoes. Productive versus unproductive hills. Proc. Soc. Hort. Science. 1905:50

13. Emery, F. E. Potato experiments, N. Y. Agr. Exp. Sta. (Geneva) Ann. Rpt. 1889:223-256.

14. Fischer, M. Einfluss von Form, Grösse und Stärkgehalt der Saatkartoffeln auf den Ernteertrag, Fühlings Landw. Ztg. 48: 88-193 201,208, 1899.

15. Fischer, M. Anbau und Vererbungsversuche mit Kartoffeln Fühlings Landw. Ztg. 49:301-307, 343-352, 369-372. 1900.

16. Fischer, M. Anbau und Verebungsversuche mit Kartoffeln, Fühlings Landw. Ztg. 50:331, 361-367. 1901.

17. Franc, H. Die Kartoffel als saatgut. 1-169. Berlin, 1878.

18. Fruwirth, C. Versuche mit Kartoffeln, Wiener Landw. Ztg. 1899:220.

19. Fruwirth, C. Versuche mit dreijahriger Auswahl je innerhalb Zweier Kartoffelnsorten, Ztschr. Landw. Versuchsw. Oosterr. 1900:400.

20. Fruwirth, C. Versuche über den Einfluss des Standortes auf Kartoffelsorten. Landw. Vers. Stat. 1903. 407-414.

21. Fruwirth, C. Die Züchtung der landwirtschaftlichen Kulturpflanzen. 4 v. Ber. 1904, 1905, 1906.

22. Girard, A. Recherches sur la culture de la pomme de terre. Par. 1891.

23. Girard, A. Recherches au su jet de l'influence attribuee a la richesse en fecule des plants de pomme de terre sur le rendement et la richesse des recoltes. Annales Agron. 19:161, 1893.

24. Goff, E. S. The influence of heredity upon vigor in the Potato. N. Y. Agr. Exp. Sta. Ann. Rpt. 1887:85.

25. Goff, E. S. The influence of heredity upon vigor in the potato. Wis. Agr. Exp. Sta. Ann. Rpt. 1899:304-308.

26. Güssow, H. T. Observations on obscure potato troubles. Phytopath. 8:507-529.

27. Hallet, F. P. Food-Plant improvement. Nature v 26; 656; 91-94. 1882.

28. Hess, W. Hannover, Landw. Forshn. Ztg. 42: Nr 33.

29. Hellriegel, H. Grundlagen des Ackerbaus 1:796. Braunschweig. 1883.

30. Knight, T. A. — On raising new and early varieties of potato. Trans Roy. Hort. Soc. London 1:157-79. 1815.

31. Knight, T. A. — Physiological and Horticultural Papers. 1-379 Lond. 1841.

32. Krzymowski, R. — Uber ein unbewurste Selection der ertragreichsten Kartoffelhorste und der ertragreichsten Exemplare Andere Kulturwächse. Fuhlings' Landw. Ztg. 1905:825.

33. Marek, E. — Die Verbesserung der Kartoffelsorten durch Auswahlstärkereicher Mutterknollen. Fuhlings Landw. Ztg. 41:164-171, 209-214, 1892.

34. Martinet, G. — Reports, Annuaire Agr. Suisse, 1900.

35. Marshall, (William) — The Rural Economy of Yorkshire. 2:51-67 1788.

36. Melhus, I. E. — Notes on Mosaic symptoms on Irish potatoes. Abs. in Phytopath, 7:71. 1917.

37. Murphy, P. A. — The Mosaic disease of potatoes. Agr. Gaz. Canada 4:345-349, 1917.

38. Macoun, W. T. — The Potato in Canada. Can. Dept. Agr. Bül. 90:1-100, 1918.

39. Orton, W. A. — Potato wilt, leaf roll, and related diseases. U. S. Dept. of Agr. B.P.I. Bul. 64:1-48, 1914.

40. Parisot, F. — Selection of Seed Potatoes, Jour. Agr. Prat. N. Agr. 9:174-176. 1905.

41. Paulson, O. — Deut. Landw. Presse. 1899, Nr 29.

42. Quanjer, H. M. — The mosaic disease of the solanceae, its relation to the Phloen-necrosis, and its effect upon Potato culture, Phytopath: 10:35-47, 1920.

43. Remy, T. — Der Einfluss von Form, Grösse und Stärk - gehalt der Saat Kartoffeln auf der Ertrag. Bl. Gersten, Hopfen Kartoffelbau. 2:71-75, 1900.

2.20.8m

44. Remy, T. Sind die innerhalb der Sorten auftretenden Schwankungen in Stärkegehalt der Kartoffelbau erblich. Bl. Gersten, Hopfen u. Kartoffelbau. 3:121-136, 1901.

45. Von Sellhorst, C. Einfluss der Grösse der Mutterhorste der Kartoffeln auf der Grösse der Ernte. Jour. Landw. 48:97-103, 1900.

46. Von Seelhorst, C. Mit Frölich G. Einfluss des ertrages der Mutterhorste auf die Hope der Kartoffelernte. Jour. Landw. 48:317-324, 1900.

47. Von Seelhorst, C. Mit Freckmann, C. Die Verebung der Kartoffeln. Jour. Landw. 52:151-162. 1904.

48. Sempolowski, A. Increasing the harvest by selecting seed potatoes. Deut. Landw. Presse 22:21, 1895.

49. Shultz, E. C., Folsom, D., Hildebrandt, F. M. and Hawkins, L.A Investigations on the mosaic disease of the irish potato. Jour. Agr. Res. 17:247-274. 1919.

50. Shultz, E. S. and Folsom D., Transmission of the mosaic disease of the Irish potato. Jour. Agr. Res. 19:315-337, 1920.

51. Stewart, F. C. Observations on some degenerate strains of potatoes. N. Y. Agr. Exp. Sta. (Geneva) Bul. 422, 319-357, 1916.

52. Stuart, Wm. Potato Breeding and Selection. U. S. Dept. of Agr. Bul. 195, 1915.

53. Sutton, A. W. The Potato. Jour. Royal Agr. Soc. of Eng. Vol. 59, 1898.

54. Thiele, P. Uber der Kartoffel als saatgut. Illus. Landw. Ztg. 1897:616.

55. Waid, C. W. Results of hill selection of seed potatoes. Amer. Breeders Assoc. 3d. Ann. rpt. 191-198, 1907.

56. Webber, H. J. Method of Improving potatoes. N. Y. (Cornell) Agr. Expt. Sta. Bul. 251:322-332. 1908.

57. Wellington, R. The uselessness of hill selection under conditions where rapid degeneration or "running out" is prevalent. Proc. Amer. Soc. Hort. Sci. 1919;175-179.

58. Whipple, O. B. Line-selection work with potatoes. Jour. Agr. Res. Vol. 19 No. 11 p 543-573, 1920.

59. White, T. H. Fertilizing and Cultural Experiments with Irish Potatoes. Md. Agr. Exp. Sta. Bul. 215, 1918.

60. Wontley, E. J. Potato Leaf roll, its diagnosis and cause. Phytopath:8:507-529, 1919.

61. Wilson, J. H. Experiments in Crossing potatoes. Trans. Highland and Agr. Soc. of Scotland vol. 19 p. 74, 1907.

62. Wholtmann, F. Uber Kartoffel Züchtung, Illus. Landw. Ztg. 1897. Nr. 34-36.

63. Wollny, E. Saat u. Pflege der Landwirtschaftlichen Kulturpflanzen 1-159. Ber. 1885.

64. Wollny, E. Einfluss des Anwelkens der Saatknollen auf den ertrag der Kartoffeln, Forsch. Agr. 18:42-57, 1893.

65. Zavitz, G. A. Potatoes, Ont. Agr. College, Bul. 239, 1916.

2.20.8m

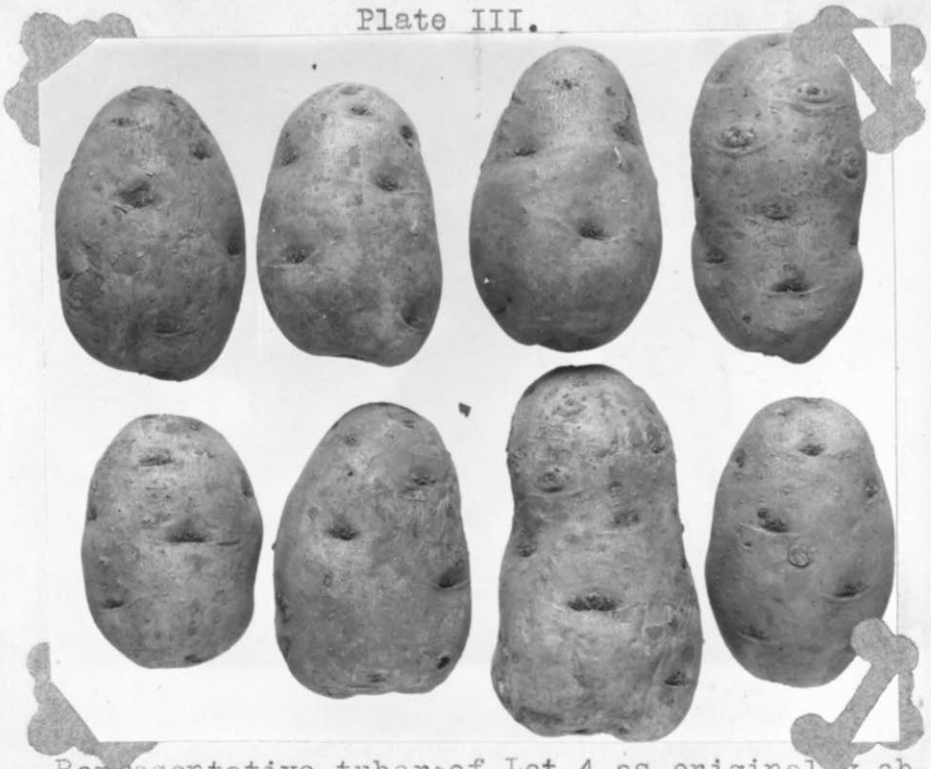
Plate I

Representative tubers of Lot 2 as originally obtained from Anoka in 1916.

Plate II.

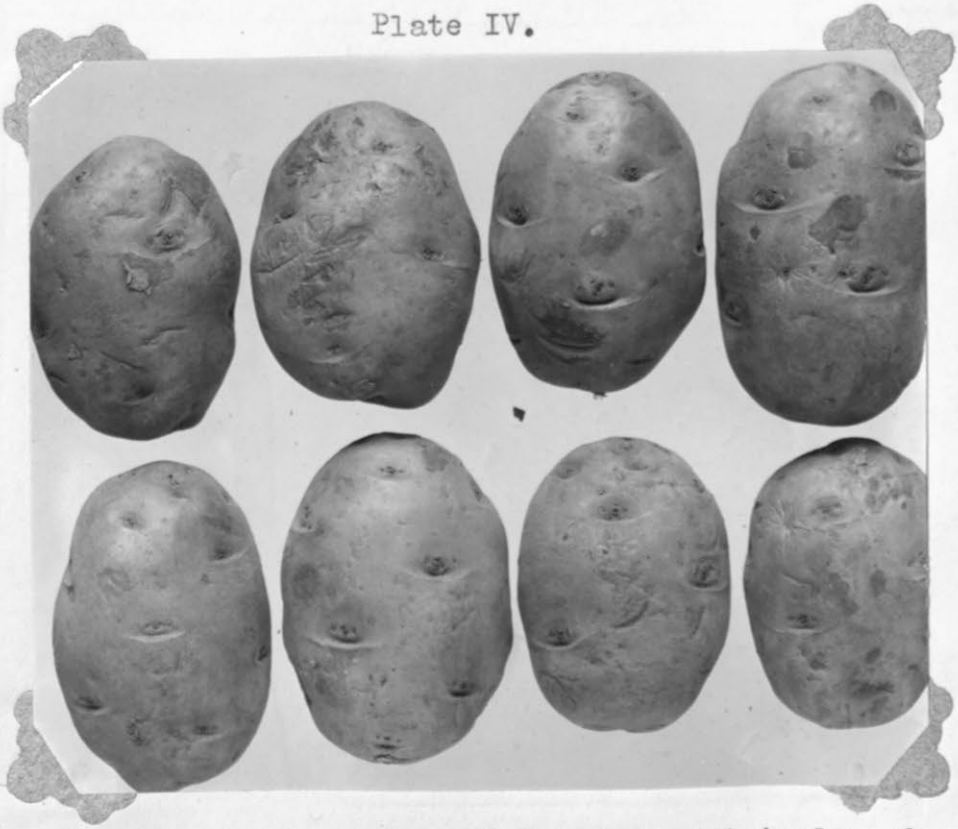
Representative tubers of lot 3 as originally obtained from Grand Rapids in 1916

Plate III.



Representative tubers of Lot 4 as originally obtained from Faribault in 1916.

Plate IV.



Representative tubers of Lot 6 as originally obtained from Duluth in 1916.

10-20 5M

Plate V.

Representative tubers of Lot 7 as originally obtained from Glyndon in 1916

Plate VI.

Representative tubers of Lot 8 as originally obtained from Hawley in 1916.