THE VALUE OF SIZE OF VINE, SET, SIZE AND SHAPE OF TUBERS AS INDEXES FOR SELECTING POTATO TUBERS IN THE BREEDING PROGRAM

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Clyde Leaon Burton

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by

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THE VALUE OF SIZE OF VINE, SET, SIZE AND SHAPE OF TUBERS AS INDEXES FOR SELECTING POTATO TUBERS IN THE BREEDING PROGRAM

I. INTRODUCTION

Some potato breeders believe that there is a correlation between seedling characters in the greenhouse and their subsequent performance in the field trials. They feel that these characters are not influenced too markedly by environmental factors, thus allowing a visual classification in discarding a large percentage of the undesirable seedlings grown in the greenhouse. If this were possible it would save time, labor and cost of planting the tubers in the field trials, as well as reducing the arduous task of hand digging them at harvest time.

Of the thousands of new potato selections that are grown in the field trials each year, less than ten percent show promise of being of any economic value.

A heterozygous plant such as the potato can be vegetatively propagated without changing the desirable genotype. With this in mind, it is hypothesized that there is a positive relationship between size, set, and shape of tubers of seedling lines in the greenhouse and the subsequent behavior of those lines in the field. It has also been assumed that the healthy, vigrous medium to large vine types in the greenhouse will produce similar vines in the field. It is generally known that potatoes with healthy, medium to large vines are far better producers of tubers than those with small vines.

Potatoes grown from true seed, and planted in the greenhouse so as to expedite breeding work, require considerable space and time. This is one of the necessary programs that must be followed in potato breeding work and little can be done to reduce the time and space at this point. The next procedure after the greenhouse phase involves the planting of the potatoes in the field for selection of desirable types. This operation requires a great deal more space and labor than that of the greenhouse. If 10,000 plants are grown in the greenhouse, this means that more than one acre of tubers will have to be grown in the field, and it can easily be seen that a method of reducing the number of tubers planted in the field would be useful.

In view of the mounting shortage of farm labor and the increased work placed upon the potato breeders and investigators, this experiment was designed to seek methods to eliminate part of the laborous task of field harvesting and still recover most of the desirable seedlings when harvested in the greenhouse.

II. REVIEW OF CITED LITERATURE

A search of potato literature revealed few observations regarding the problem studied. Most of the literature has to do with certain physiological factors or results affecting the growth of the potato plant in one way or another.

Livermore (2), studying the correlation of seedling performance in the greenhouse and their subsequent yield in the field with 2,000 seedlings of several varietal crosses, found that the association between greenhouse growth and yield in the field was not very strong. "The coefficient of correlation in all cases was too low to permit any confidence in using seedling size in the greenhouse as a means of selecting the better producers."

Bushell (1) found that the number of plants per hill within the ordinary range of one to five, is itself not an important factor in yield of potatoes. As a general rule, an increase in number of stalks per hill increases the number of tubers per hill.

Werner (3) reports that a new sprout is almost entirely dependent upon the seed piece until the first leaves are sufficiently developed to manufacture more food than they can use. This means that potato plants generally draw upon the old seed piece until the plants are eight to 12 inches tall.

III. EXPERIMENTAL PROCEDURE

The greenhouse planting was made at the Michigan Agricultural Experiment Station in East Lansing. In the mid-summer of 1950, seeds from eight scab resistant crosses were planted in flats in the greenhouse. When the seedlings were from one-half to one inch in height, approximately 1,000 seedlings representing eight crosses were transplanted to three and one-half inch clay pots that were placed on the greenhouse benches. Here the seedlings were allowed to grow until the last of November at which time they were harvested. The potato seedlings were grown in number 2 plastering sand, were watered regularly and were supplied with a standard nutrient solution to secure the best growth under fall greenhouse conditions. The temperature varied from 65 to 75 degrees F. No artificial lights were used during the experiment. No unusual conditions were observed in the greenhouse.

A population of only 1,000 plants was used because of the exacting and time-consuming measurements that had to be made. After approximately 15 weeks of growing, when ten percent of the leaves showed yellowing, the plants were harvested. The greenhouse data included a classification of the vines into three groups; small medium and large, according to the height and fullness of the vine. A more accurate measurement of the vine size was also made using a relative scale of one to ten. The very smallest vines were called one, and the very largest vines, ten. The smallest vines were approximately four inches in height and the largest vines approximately 16 inches in height (Figure I and II). The class range was

1 3/8 inches. By placing the vines into ten classes, it was believed that this would give a better indication of growth of each plant than by merely classifying the vine as small, medium, or large. The vines were also noted as being thin, medium, or heavily leaved. Vines observed as small were measured and recorded as 1, 2, 3 thin, 3 medium, and 4 thin. Those vines observed as medium were in classes 3 heavy, 4 medium, 4 heavy to 6 thin, 6 medium, and 7 thin. The vines observed as large were in classes 6 heavy, 7 medium, 7 heavy to 10 heavy. This was true of all three measurements; greenhouse, July 17 and August 20. At the same time data were recorded as to the number of tubers set, and the length and width to the nearest tenth of a centimeter of all tubers.

The tubers from each plant were placed in a one pound kraft bag on which was indicated the plant number. Those of a cross were put together in a sufficient number of 25 pound bags on which was indicated the cross number. They were then placed in storage until planting time in the spring.

The field studies of the problem were conducted at the Michigan Agricultural Experiment Station at Lake City, Michigan. Planting date was May 30, 1950.

The largest tuber from each vine harvested in the greenhouse was planted as a one hill unit in the field. The hills were spaced 18 inches apart and there were 40 hills per row. The distance between rows was 36 inches. The soil was relatively uniform and was

considered to be desirable for high potato production. Standard cultural practices, such as fertilization, spraying, irrigation, cultivation, etc. were carried out through the growing season. There were no unusual weather conditions during the summer. Although there was a severe epiphytotic of late blight in the area, the experiment station kept ahead of the disease by continuous spraying and, as a result, none of the plants in this experiment were seriously infected.

On July 17, when the potato plants were in full flower (Figure III) a measurement of the growth of vines was taken by using a relative scale from one to ten. The very smallest vines, or the number one class, were approximately five inches high, and the largest, the number ten class, were approximately 19 inches high. The class range was 1 5/8 inches. It was also noted as to whether the vines were thin, medium, or heavily leaved. The plants were observed as being small, medium, or large in height. At the same time another observation was made on the large plants as to whether they had healthy, vigorous vines or non-healthy, spindly vines.

On August 20th, when 15 percent of the vines were beginning to turn yellow (Figure IV), the same procedure used on July 17th, as to note taking, was again followed. The relative scale had to be revised to compensate for the progress made in vine growth. The average height of the number one class potato vines was seven inches,

and the approximate height of the number ten vines was 26 inches. The class range was 2 1/4 inches.

During the first week in September the experiment was harvested. Each hill was dug separately by hand (Figure V). The data recorded included the number of tubers per hill over one-half inch in diameter. This was to determine the relationship between number of potatoes set in the greenhouse and the number produced in the field. The number of stalks per hill was noted. So as to obtain a statistical analysis of tuber shape and size, the length and width, to the nearest tenth of a centimeter, of the largest tuber from each hill was taken. A note as to the tuber selection rating of each hill, whether "poor", "fair", "good", or "excellent" was recorded. Of the original 1,000 seedling lines grown in the greenhouse, approximately 915 were harvested. The indicated reduction in numbers of lines was due to various factors. No losses were due to failure to germinate or due to diseases.

The degree of association of several of the characters studied was determined by the coefficient of correlation.

IV. RESULTS AND DISCUSSION

The probability of obtaining a relationship between the performance of potato seedling lines grown in the greenhouse and their subsequent behavior in the field is complicated by the self-evident fact that the two phases of the experiment were grown under different environmental conditions.

It is difficult to determine when size and habit of vine, set, size, shape and selection rating of tubers are the result of genetic factors, or when they are the result of non-gentic factors. It is assumed that the differentiation, development, and proper functioning of the vegetative organs of plants would be influenced somewhat in the same way, if all plants were grown under identical environmental conditions. In other words, if the soil, light, and moisture were such that they would induce vines to grow taller, then proportionately, all vines would be taller. The potato seedlings were grown under unform conditions both in the greenhouse and in the field.

Size of Vine

In general there seems to be a practical relationship between greenhouse vine size and field vine size. The average coefficient of correlation between vine size in the greenhouse and in the field, July 17, was 0.52; and in the field, August 20, was 0.47, Table 1.

Table 2 is a table obtained from the scatter-diagrams of the eight crosses. It shows the greenhouse vine sizes and the relative rank of the vine sizes when measured July 17, and again on

August 20. The rating of a vine as small in the greenhouse does not mean that the tuber from that small vine will always produce a small vine in the field. This similar condition is also true for vines rated as medium or large in the greenhouse. It should be noticed, however, that 83 percent of the lines producing large vines in the greenhouse produced large vines in the field on July 17, and that 31.8 percent of the lines producing medium vines in the greenhouse produced similar sizes in the field, and that 73 percent of the lines rated small in the greenhouse were rated as small or medium in the field. While there was not as strong a relationship as might be desired, the relationship was strong enough to be of practical value.

Table 3 gives the distribution of the various seedling lines when grouping is made according to date when observational notes were taken on vine-size, (large, medium, or small) and according to the tuber-selection rating made in the field at harvest time. Only lines whose tuber rating was "excellent" were likely to have passed the harvest-time screening test.

TABLE 1

THE COEFFICIENT OF CORRELATION OF THE DIFFERENT FACTORS COMPARED WITHIN THE EIGHT CROSSES

Factors correlated	Number of cross								
	1	2	3	4	5	6	7	8	Av.*
GH** vine height July 17 vine height	.30	.64	.47	.51	.56	.52	.40	.56	..52
GH vine height Aug. 20 vine height	.32	.42	.38	.49	.53	.45	.39	.49	.47
GH tuber set Field tuber set	.37	.19	.11	.36	.17	.13	.10	.25	.21
GH tuber set Field set/stalk	.21	.14	.19	.39	.40	.29	.20	-	.27
GH tuber length Field tuber length	.13	.29	.26	.13	.39	.29	.40	.25	.27
GH tuber width Field tuber width	.20	.27	-	.30	.40	.38	.25	.27	.32
GH tuber ratio Field tuber ratio	.29	.49	.45	.44	.29	-	-	-	.41
Population of each cross	99	103	49	69	83	361	53	143	
Degrees of freedom	97	101	47	67	81	314	51	141	
Level of significance at 5%	.195	.195	.288	.232	.217	.113	.273	.159	
Level of significance at 1%	.254	.254	.312	.283	.148	.354	.208		

* Z value used
** Greenhouse

TABLE 2

TWO WAY TABLES SHOWING GREENHOUSE VINE SIZE AND THE RELATIVE RANK OF THE VINE SIZES WHEN MEASURED JULY 17 AND AUGUST 20

GREENHOUSE	Small		Medium		Large		
	No. Plants	Per Cent of Total	No. Plants	Per Cent of Total	No. Plants	Per Cent of Total	Total
			July 17				
Small	50	16.0	179	57.2	84	26.8	313
Medium	16	4.2	121	31.8	244	64.0	381
Large	3	1.4	34	15.4	184	83.2	221
Total	69		334		512		915
			August 20				
Small	112	35.8	170	54.3	31	9.9	313
Medium	43	11.3	239	62.7	99	26.0	381
Large	8	3.6	105	47.5	108	48.9	221
Total	163		514		238		915

It is seen that of the lines whose vine size was classed as small in the greenhouse only three produced "excellent" tubers. By discarding all small plant lines in the greenhouse a considerable reduction, 34 percent, in the field layout could be made. These same three lines represent 10 percent of the total number of lines with tuber rating of "excellent". The saving in field work would seem to warrant this lost however.

When the observational notes were taken at flowering time, 258 plants were recorded as having large, healthy, vigorous vines. The harvest time data on tuber type showed that, within this group of 258 plants there were included all but one of the "excellent" hills and all but 12 of the "good" hills.

When the observational notes on vine size were made one month later (August 20), only 160 plants were indicated as having large, healthy, vigorous vines. These included 15 (or 50 percent) of the "excellent" tuber hills and 45 out of 113 "good" tuber hills. This was a considerable drop in accuracy of prediction when compared with the notes taken at flowering time. On July 17 (Table 2) there were 512 plants measured as large, August 20 there were only 238 large vines. This may indicate that a certain few vines grew more rapidly than the majority of the other vines, thus alterating the predictions in such a way that an accurate picture of the field could not be seen. The vines that produced considerable vegetative growth after flowering time generally set "poor" tubers. It also appeared that the

TABLE 3

THE NUMBERS AND PERCENTAGES OF SEEDLING LINES IN EACH OF THE FOUR HARVEST-TIME, FIELD, TUBER-SELECTION RATINGS ARE GIVEN FOR EACH OF THE THREE VINE SIZES ON EACH OF THE THREE DATES OF VINE-SIZE CLASSIFICATION

Vine Sizes	Numbers of Lines					Percentages of Lines				
	Field tuber-selection ratings					Field tuber-selection ratings				
	Poor	Fair	Good	Excel.	Total	Poor	Fair	Good	Excel.	Total
GREENHOUSE										
Small	200	90	20	3	313	63.9	28.7	6.4	1.0	100.
Medium	152	163	51	15	381	39.9	42.8	13.4	3.9	100.
Large	81	86	42	12	221	36.9	38.9	19.0	5.4	100.
FIELD JULY 17										
Small	66	3	0	0	69	95.6	4.4	0.0	0.0	100.
Medium	206	112	15	1	334	61.7	33.5	4.5	0.3	100.
Large	161	224	98	29	512	31.4	43.8	19.1	5.7	100.
FIELD AUGUST 20										
Small	133	27	2	1	163	81.6	16.6	1.2	0.6	100.
Medium	233	209	59	13	514	45.3	40.7	11.5	2.5	100.
Large	67	103	52	16	238	28.2	43.3	21.8	6.7	100.
Sum of each date	433	339	113	30	915					

majority of the "excellent" and "good" tuber vines made little growth in comparison with the "fair" and "poor" tuber vines.

If these data are interpreted correctly, one could be reasonably sure of selecting the best hills by placing a small marker beside the vigorous vines at flowering time and harvest only those by hand. This would leave about 72 percent of the hills to be dropped from the breeding program and dug by machine.

Tuber Set

There appeared to be no strong practical relationship between the number of tubers set in the greenhouse with those set in the field (Table 1). A plant that produces only one tuber in the greenhouse could produce ten in the field. The average set in the greenhouse was three, while the average set in the field was six. Those hills having more than one stalk per hill produced more tubers per hill, but not in a ratio fashion, These results agree with those of Bushell (1).

Tuber Size

When the greenhouse and field tuber sizes were correlated, there was found to be little relationship between the two sizes. The coeficients of correlation, 0.27 for length and 0.32 for width, are too small to be of value in potato selection work. Length and width appear to be characters which are greatly influenced by environment and ability to measure the greenhouse tubers accurately.

When a closer analysis of the data was made, it was observed that when the largest tuber of a greenhouse plant was two centimeters, or less, in length and width, it seldom produced a "good" or "excellent" hill in the field. Out of the 210 tubers that were two centimeters, or less, in length and width, only three produced "good" or "excellent" hills. In general, these potatoes produced vines that fell in the small group when measured in the greenhouse and field.

If it were possible to grade out all plants that produce no tubers larger than two centimeters in length in the greenhouse, about one-fourth of the field labor would be saved.

The average size of the largest greenhouse tubers producing "excellent" hillswas 3.9 centimeters length and 3.3 centimeters in width (Table 4). The average size for all the greenhouse tubers (largest tuber per plant) was 3.0 centimeters in length and 2.6 centimeters in width. These average sizes may have an important bearing on the interpretation of the data. It may be that, if the greenhouse average tuber size were larger, one could discard tubers larger than two centimeters in length. The small tubers may have had insufficient food material to develop very rapidly during the first of the growing period, thus never producing a good vine or tuber set (Werner, 3).

Tuber Shape

When the ratio of length to width for the largest tuber per plant in the greenhouse was correlated with the largest tuber of the progeny in the field, the relationship was not strong enough to be useful in selection work. The average correlation for the five crosses was 0.41. One of the probable reasons for this low degree of relationship was that a large percentage of the potatoes grown in the greenhouse were too small to be measured accurately enough for indexing purposes.

At the time of field harvesting many of the original greenhouse tubers were recovered still in tact. The form of the original tuber, when large enough, corresponded surprisingly with the form of the tubers in the field hill.

It is suggested that a more careful analysis of this phase be carried out by the use of only the larger tubers (those over 2 centimeters in length) in a cross and that a template be used to see whether off-shaped tubers produced in the greenhouse will produce off-shaped tubers in the field.

Tuber-Selection Rating

Of the total of 915 seedling lines which were harvested and for which complete data were available, there were only 30 lines rated as "excellent" and so worthy of saving for further selection purposes. The criteria of yield, uniformity in size, and desirability of shape of the tubers were used in determining

tuber selection rating. There were 113 hills considered "good", 339 hills rated "fair", thus leaving a total of 433 "poor" hills. Table 4 shows the measurements of the thirty hills that produced "excellent" tubers.

TABLE 4

DATA ON THE THIRTY LINES THAT PRODUCED EXCELLENT TUBERS IN THE FIELD

* GH Vine Size	July 17 Vine Size	Aug. 20 Vine Size	No. Tubers Set in GH	No. Stalks Per Hill	No. Tubers Set in Field	GH Tuber Length (L)	GH Tuber Width (W)	Field Tuber Length (l)	Field Tuber Width (w)	GH Tuber Ratio, L/S	Field Tuber Ratio, l/w
						cm	cm	cm	cm		
10	10	7	3	3	14	3.8	3.4	9.1	8.1	1.1	1.1
10	10	8	3	3	7	4.3	3.8	8.0	7.8	1.1	1.0
10	10	7	2	1	5	4.6	3.9	8.5	8.0	1.2	1.1
10	9	6	2	4	18	5.4	4.7	8.2	7.5	1.1	1.1
9	10	7	2	4	12	5.5	4.8	8.2	7.2	1.1	1.1
9	9	8	6	1	9	3.7	3.7	9.9	8.0	1.0	1.2
8	10	8	4	1	10	4.0	3.4	9.9	9.5	1.2	1.0
8	10	10	3	1	7	3.9	3.1	7.5	7.3	1.2	1.0
8	9	5	6	1	6	3.8	3.5	8.2	8.5	1.1	1.0
8	8	8	3	2	11	4.9	4.1	8.1	7.6	1.2	1.1
7	8	10	2	2	11	4.0	3.1	9.3	7.5	3.1	3.2
6	10	9	2	1	7	4.0	3.1	8.0	8.0	1.3	1.0
6	8	5	3	1	5	3.9	3.6	9.1	9.3	1.1	1.0
5	8	6	3	1	6	3.4	2.8	7.5	7.7	1.2	1.0
5	10	8	4	1	8	3.2	2.2	8.0	7.4	1.4	1.1
5	8	9	1	1	9	3.2	2.4	8.5	7.5	1.3	1.1
5	8	6	1	1	5	3.6	3.5	8.1	7.8	1.0	1.0
5	8	5	3	2	10	5.2	3.5	7.2	7.2	1.5	1.0
5	8	6	2	1	6	2.5	2.8	7.1	7.4	0.9	1.0
5	9	6	3	1	5	2.6	2.4	8.1	6.7	1.1	1.2
5	7	5	2	1	6	3.0	2.4	8.3	8.3	1.2	1.0
4	9	6	1	2	10	4.5	3.3	9.0	8.0	1.3	1.1
4	9	6	2	1	11	2.9	1.9	10.4	7.6	1.5	1.5
4	9	6	1	1	7	1.8	1.7	9.0	9.0	1.0	1.0
4	9	7	2	1	6	3.1	2.5	8.9	7.8	1.2	1.1
4	8	8	1	1	4	2.8	2.3	9.9	7.9	1.2	1.2
4	8	7	2	2	12	3.2	2.5	11.0	8.0	1.3	1.4
3	4	3	3	1	13	3.0	2.3	9.1	8.0	1.3	1.1
3	8	5	2	1	7	2.9	2.1	6.5	6.7	1.4	1.0
3	9	6	2	1	8	2.2	1.5	9.0	8.0	1.4	1.1

* Greenhouse

V. SUMMARY

The purpose of this study was to determine whether there is a relationship between the growth of potato seedlings in the greenhouse and subsequent performance of the same clonal lines in the field. If there were a relationship, would it be sufficiently high to warrant using certain characters as a basis of judgment in potato seedling selection?

About 1,000 potato seedlings, representing eight different crosses, were grown in the greenhouse. The largest tuber harvested from each greenhouse vine was planted in the field. Measurements from both phases included relative vine size, number of tubers set and length and width of tuber. At field harvest time the hills were given tuber selection ratings.

Methods were discussed which would aid in selecting the plants that produced the best hills or in discarding those plants that produced the non-selected hills. In brief, two types of plants could have been discarded in the greenhouse; those that were small or in the lower three classes of vines, 34 percent of the greenhouse planting, or those plants that did not produce tubers larger than two centimeters in length, 23 percent of the greenhouse planting.

This small vine group unfortunately also contained 16 percent of the lines whose tubers were rated "good" or "excellent" at field harvest time. Discarding those lines whose greenhouse tubers were two centimeters, or less, in length would have included only three lines, or two percent of the "good" and "excellent" tubers.

Relative vine size in the greenhouse and in the field at flowering time were found to be positively and strongly enough associated to be of value in selection work.

Set, size and shape of tuber in the greenhouse were not strongly associated with the similar characters of the field grown tubers. However, the greenhouse tubers less than two centimeters in length, on the whole, produced low rating potatoes in the field.

The selection of the healthy, vigorous large plants at flowering time included only 28 percent of the entire field but 90 percent of the hills subsequently rated "good" or "excellent".

FIGURE I

Greenhouse potato seedlings just before harvesting.

FIGURE II

The ten classes of potato vines measured in the greenhouse. The number one class is on the left.

FIGURE III

Potato seedlings growing at Lake City. Picture was taken during the first field measuring date, July 17.

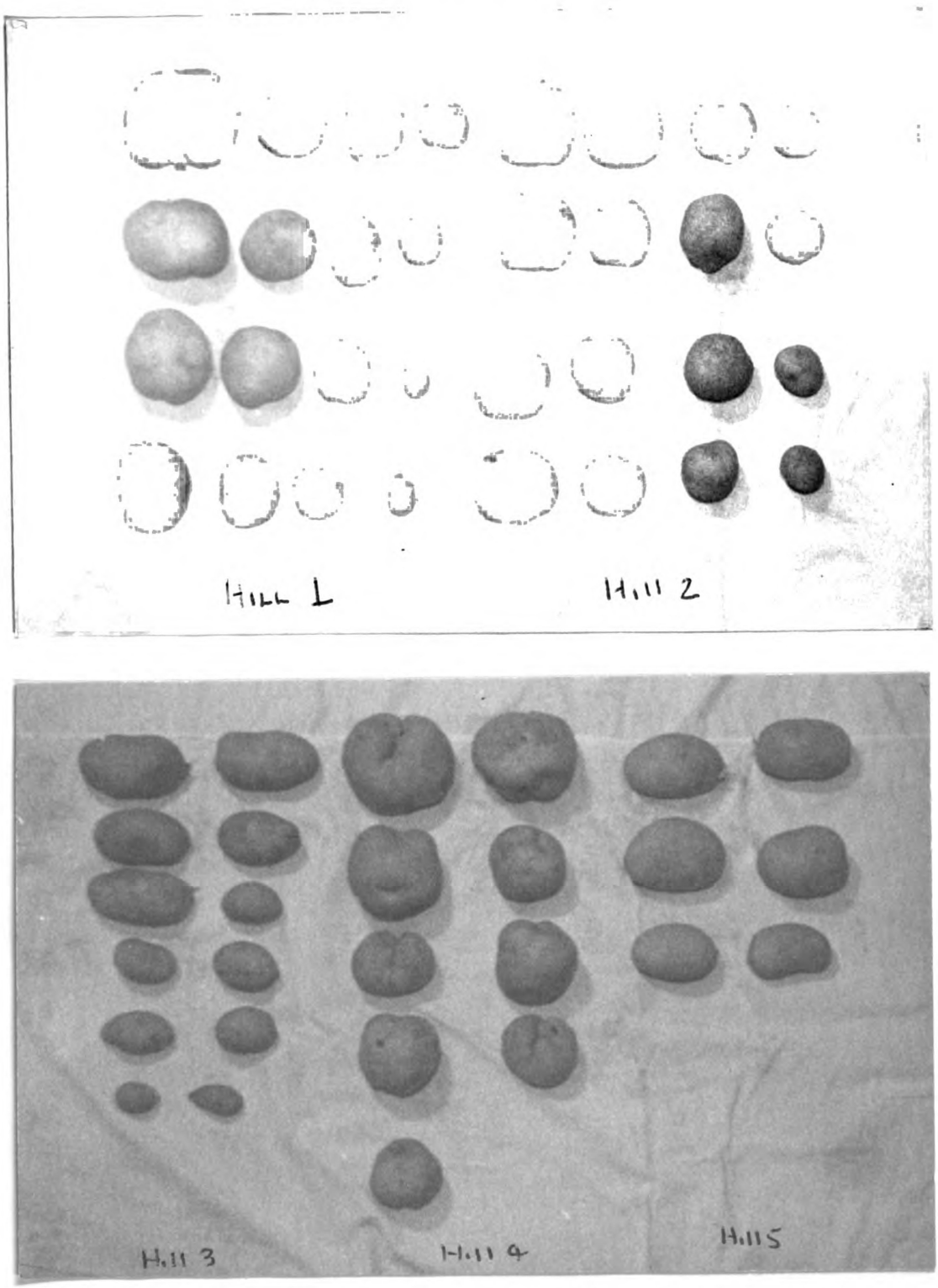
FIGURE IV

Potato seedlings growing at Lake City during the second field measuring date, August 20.

FIGURE V

Two photographs showing how the potatoes were piled in hills after being hand dug. The hills were now ready to be rated as to selectibility.

FIGURE VI



Two photographs showing the maintenance of tuber shape throughout different hills that were harvested in the field.

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