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INFLUENCE OF FREEZING OF SEED POTATOES ON VIABILITY AND YIELD[1]

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INTRODUCTION

Potato growers in some parts of the United States are confronted every year with the problem of deciding whether to discard outright or attempt to use potato seed stock that has been more or less injured by freezing in storage or transit. There are two important factors to take into consideration before deciding this question: (1) The amount or extent of injury in the stock on hand; and (2) the availability of new stock free from injury and the cost of replacing injured seed stock with new stock. This bulletin gives the results of a series of experiments conducted to determine the effect of freezing on potato seed stock.

PLAN OF THE EXPERIMENTS

In the work herein reported a study was made of the effect on yield resulting from the use of frozen seed potatoes showing varying degrees of injury. The potatoes used were frozen under controlled laboratory conditions. The purpose was to study the comparative yield of frozen seed stock with the same stock known to be free not only from freezing injury but to have been entirely free from exposure at any time to conditions that might result in freezing injury.

The varieties of potatoes studied were Irish Cobbler, Green Mountain, and Triumph, each a distinct strain of superior quality for

[1] The investigations here reported were carried on cooperatively under the projects fruit and vegetable handling, storage, and transportation and potato investigations. Each writer assumes equal responsibility for the results given.

seed purposes. The experiments were commenced in 1922. During that year and in 1923 and 1924 the work was carried on with stock exposed to freezing at the cold-storage laboratory at the Arlington Experiment Farm, Rosslyn, Va., and shipped to Presque Isle, Me., to be planted. Owing to certain undesirable features of the original plan, it was decided in 1924 to continue the investigation at the

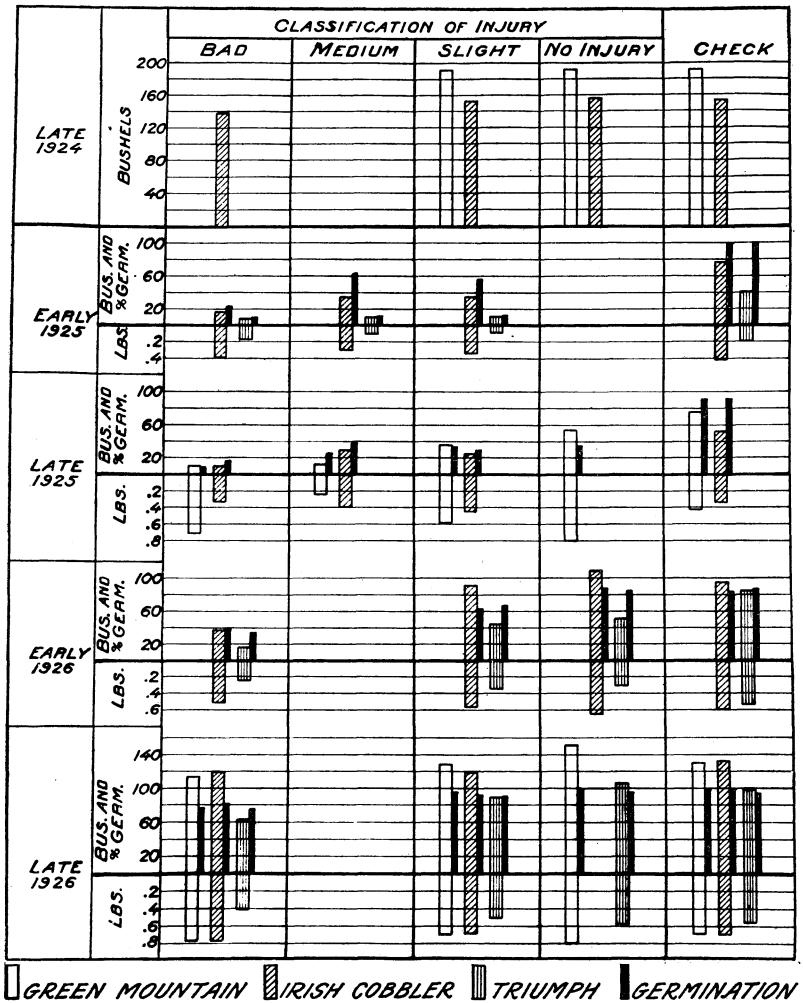

FIGURE 1.—Yields in bushels per acre and in pounds per hill and percentage of germination of potatoes at Arlington farm

Arlington farm. Although a planting was made in Maine that year, work was also started at the Arlington farm and continued through 1925 and 1926.

The method employed each season in freezing the potatoes was as follows: Barrel lots of each variety were removed from the regular 40° F. storage room and spread out on a platform in a layer one tuber

deep at a temperature of 25° for 18 hours. They were then gathered and tossed into a basket in such a way as to jar but not bruise them and again were spread out. Experience has shown that this method of handling usually starts freezing in potatoes that are undercooled below their freezing point, which is about 29°,[2] without actual freezing having taken place.[3] After an additional three hours of exposure at the temperature of 25°, the potatoes were removed to a room held at a temperature ranging from 60° to 70°. After two or three days, all soft and wet specimens were discarded, and the remaining tubers were usually put back into 40° storage until desired for use.

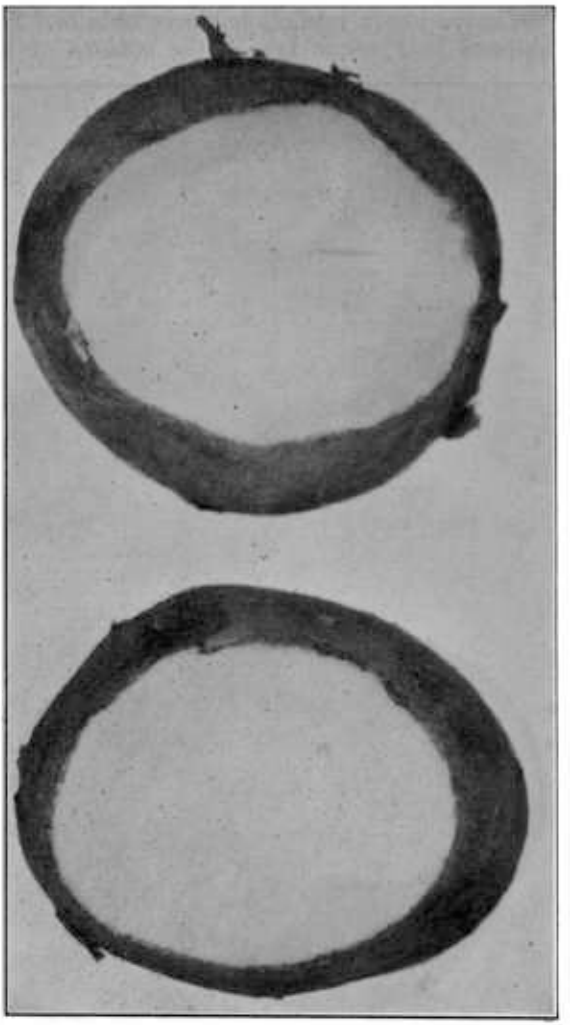

FIGURE 2.—Stem end of potatoes cut off, exposing the freshly cut tissues. No freezing injury is apparent

In 1922 the stock was subjected to freezing late in April, as described. Soft, wet specimens were removed, and the remainder were shipped immediately to Maine to be planted. In 1923 and 1924 duplicate lots of stock were treated in both January and April. Lots exposed in April were shipped immediately, together with those exposed in January which had been held in 40° storage. Satisfactory comparisons between the lots exposed and held in storage and those exposed and shipped immediately for planting could not be made because of inevitable variations in treatment. The potatoes shipped to Maine were not classified as to the extent of injury, as was done at the Arlington

[2] WRIGHT, R. C., and TAYLOR, G. F. THE FREEZING TEMPERATURES OF SOME FRUITS, VEGETABLES, AND CUT FLOWERS. U. S. Dept. Agr. Bul. 1133, 8 p. 1923.

[3] WRIGHT, R. C., and TAYLOR, G. F. FREEZING INJURY TO POTATOES WHEN UNDERCOOLED. U. S. Dept. Agr. Bul. 916, 15 p., illus. 1921.

farm. The treated lots were all classed as frozen, and the resultant yields were compared directly with check lots of untreated material from the same source.

RESULTS AT PRESQUE ISLE, ME.

The yields in bushels per acre obtained from the seed frozen and shipped to Presque Isle in the seasons of 1922, 1923, and 1924 are shown in Table 1. Owing to the practical impossibility of duplicating precise conditions, such a variation in degree of injury existed between the lots frozen in January and those treated in April that it seems more reasonable to account in this way for the differences in yield between lots frozen at the two periods, rather than to attribute these differences to the relatively long period of storage after freezing in the lots treated in January. A study of Table 1 shows an average yield for the three seasons of prime potatoes from frozen Green Mountain seed of 266.34 bushels per acre, calculated from actual yields per row, as compared with 304.43 bushels from the check or untreated potatoes, thus revealing a loss of 38.09 bushels per acre. The average yield from frozen Irish Cobbler potatoes was 282.76 bushels per acre of primes against 309.83 bushels from the untreated Irish Cobblers, a loss of 27.07 bushels due to freezing injury. Frozen Triumph seed potatoes yielded 112.4 bushels per acre, whereas unfrozen seed yielded 207.77 bushels, a loss of 95.37 bushels. Although the average figures show a loss in yield from planting frozen seed, certain

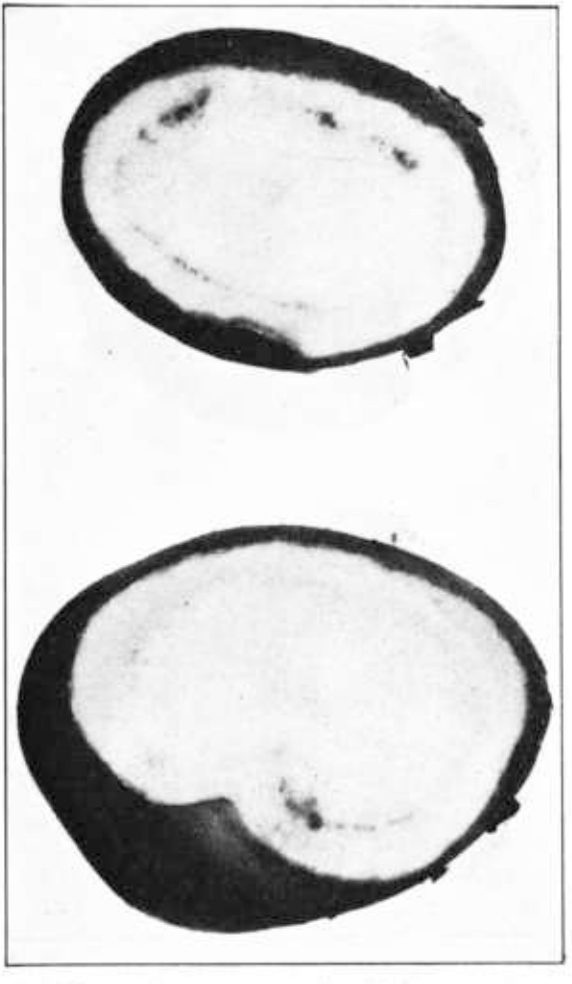

FIGURE 3.—Slight freezing injury shown at the stem end of the potato

instances show individual yields from frozen seed to be as high as from the checks, or higher.

The percentage of germination from frozen and check potatoes as given in Table 1 shows a decrease in every instance, due to freezing injury.

TABLE 1.—*Acre yields and percentages of germination obtained from frozen seed potatoes at Presque Isle, Me., in 1922, 1923, and 1924*

Variety and treatment	Yields per acre							Germination			
	1922		1923		1924		Average of primes	1922	1923	1924	Average
	Primes	Culls	Primes	Culls	Primes	Culls					
Green Mountain:	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Frozen in January	------	------	376.7	38.3	181.6	5.8	266.34	-----	95.0	65.4	81.88
Frozen in April	255.1	57.9	236.7	36.7	281.6	12.0		94.4	61.0	93.6	
Check	268.3	65.8	385.0	70.0	260.0	10.0	304.43	98.7	99.0	96.0	97.9
Irish Cobbler:											
Frozen in January	------	------	390.0	55.0	125.0	3.0	282.76	-----	94.0	82.4	87.66
Frozen in April	308.0	77.0	365.0	41.7	225.8	15.0		93.5	72.0	96.4	
Check	266.2	136.1	433.3	60.0	230.0	12.5	309.83	95.4	97.0	97.6	96.7
Triumph:											
Frozen in January	------	------	116.7	41.7	64.1	4.1	112.4	-----	96.0	41.6	65.76
Frozen in April	98.7	50.9	90.0	15.0	192.5	23.3		46.0	52.0	93.2	
Check	268.3	65.7	180.0	41.7	175.0	25.0	207.77	87.0	98.0	97.6	94.2

RESULTS AT ARLINGTON EXPERIMENT FARM

In the experiments conducted at the Arlington Experiment Farm two plantings were made each year—one in April and a later one in July. In each instance the seed was subjected to freezing, as already described, about two weeks before planting time. The method pursued, however, differed from the one followed in Maine in that previous to planting the potatoes of each lot were classified according to the degree of injury, and these classes for each variety were planted separately. In order to determine the extent of injury, a thin transverse slice sufficiently deep to expose all tissue across the stem end was cut from each exposed tuber. The potatoes of each variety were thus arbitrarily classified according to the extent of freezing injury on the basis of the discoloration apparent in the freshly cut tissue.

In 1924 and in 1926 these were classified in groups designated as "bad," "slight," and "no injury." In 1925 an additional group designated as "medium" was used. Those classed as bad showed definite necrosis of the vascular system with large dark blotches scattered over the cut surface of the tubers, indicating considerable cellular breakdown; those classed as slight usually showed a few small dark-gray spots or a slightly grayish discoloration near the vascular ring; those classed as medium showed a rather intermediate stage between slight and bad necrosis. In the seasons when the medium classification was not used the tubers that would have gone into this group were divided between the slight and bad groups, depending upon the degree of discoloration apparent. The potatoes classed as showing no injury presented a normal appearance in every

respect and could not be distinguished from potatoes that had not been exposed to freezing temperatures. All of these potatoes undoubtedly were undercooled—that is, they were cooled down below the freezing point, since they were left for 21 hours at the low temperature, but owing to some particular characteristics they did not freeze even after being jarred and thrown into the basket.

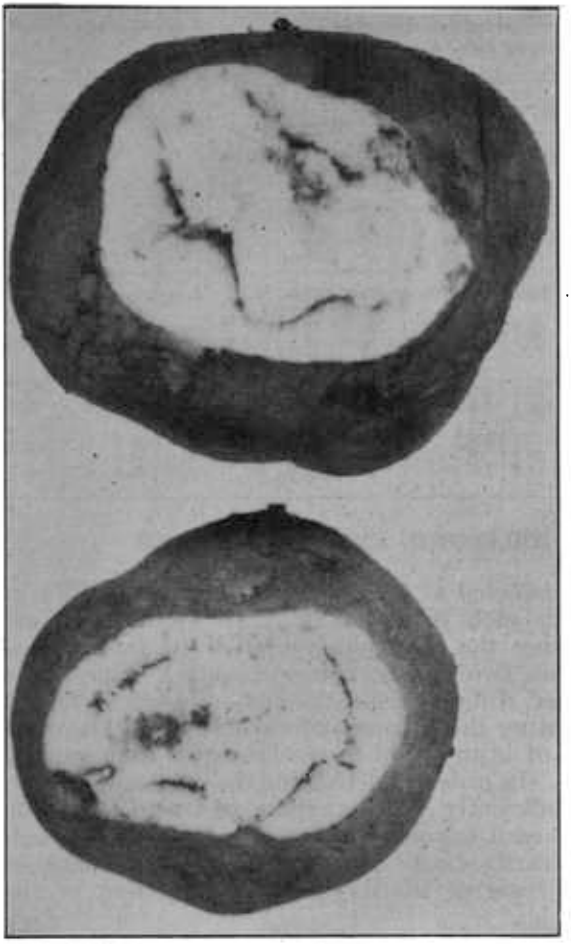

FIGURE 4.—Bad freezing injury shown at the stem end of the potato

In the classifying of the potatoes a certain number of soft-type individuals were found, as described by Wright and Diehl in another publication,[4] which, on cutting, showed no discoloration but proved to be actually killed by freezing, and these decayed when left for six or eight days at the warm-room temperature. These specimens were distinguished from normal potatoes largely by the odor, when cut within one or two days after exposure and before actual decay commenced. Such specimens have a rather sour odor, as distinguished from the characteristic smell of freshly cut normal potatoes, and are also inclined to be slightly softer and to cut without the characteristic crackle of normal potatoes. It was necessary to exert some care in separating these specimens from the no-injury group.

All the potatoes, including the check rows of those unexposed, were planted as soon as possible after the seed pieces had been cut. The planting scheme was to arrange hundredth-acre rows in the following order: Bad injury, slight injury, no injury, and check. Each group was replicated three or four times with each variety, depending upon

[4] WRIGHT, R. C., and DIEHL, H. C. FREEZING INJURY TO POTATOES. U. S. Dept. Agr. Tech. Bul. 27, 24 p., illus. 1927.

the quantity of material available. Hand-cut seed pieces of approximately the same size were planted 14 inches apart.

The average yields of both prime and cull stock, calculated as bushels per acre for all classes of injury in each variety throughout the experiments, are given in Table 2; and the percentages of germination of seed in each lot and the yield in ounces per hill are given in Table 3. The low yields for both early and late crops for 1925 will be noted. They were due to unusually adverse growing conditions throughout the season. As expected, judging from the appearance of the potatoes classed as bad, a satisfactory germination

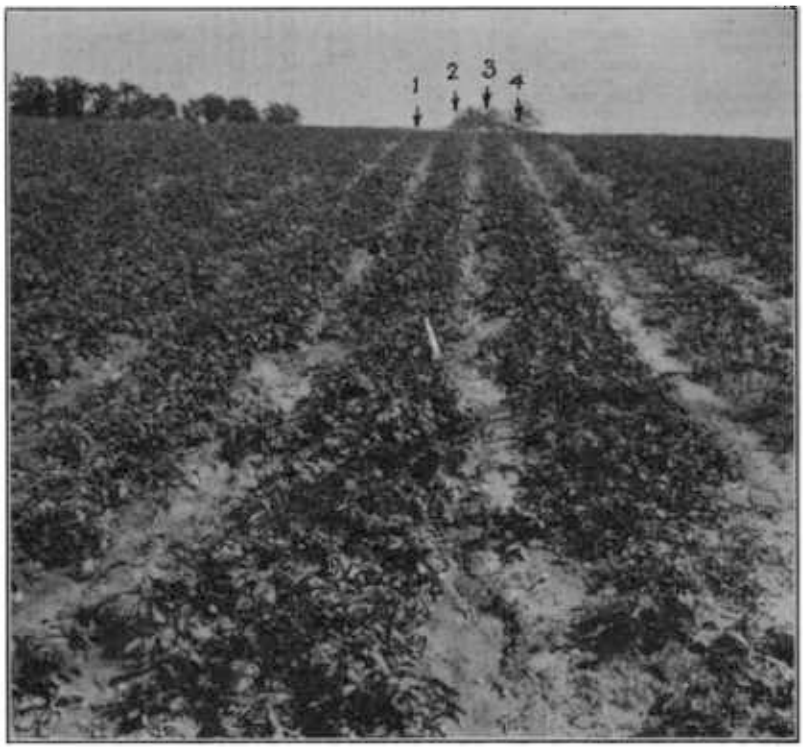

FIGURE 5.—Green Mountain potatoes from frozen seed photographed in the field. Row 1, check, seed not exposed to freezing; row 2, seed exposed to freezing, but showing no injury; row 3, seed showing slight freezing injury; row 4, seed showing bad freezing injury

and yield in this group was not obtained. The extent of injury in potatoes of this class included much of the tissue immediately surrounding the eyes and in some cases included them. Those classed as slight gave a varying germination from rather low to almost as good as the checks, apparently depending upon conditions favorable for germination. When the weather was quite favorable, as in the case of the late crop in 1926, the percentage of germination in this class equaled that of the check. In most cases the yield from those classed as no injury was equal to that of the checks, whereas the average of all crops showed a slight advantage in yield in favor of those classed as no injury.

TABLE 2.—*Acre yields obtained from frozen seed potatoes at Arlington Experiment Farm, 1924–1926*

Variety	Crop	Degrees of freezing injury								Check	
		Bad		Medium		Slight		None			
		Primes	Culls	Primes	Culls	Primes	Culls	Primes	Culls	Primes	Culls
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Green Mountain	Late, 1924	------	------	------	------	192.0	14.1	191.7	24.2	192.2	26.2
Irish Cobbler	do	138.3	8.3	------	------	152.5	11.7	156.7	13.3	152.1	7.9
Do	Early, 1925	15.5	7.0	35.2	18.5	35.2	13.9	------	------	76.9	36.1
Triumph	do	8.1	6.7	9.7	9.3	11.2	9.7	------	------	40.6	24.3
Green Mountain	Late, 1925	11.3	4.2	12.0	12.8	36.5	13.6	54.2	19.0	76.3	24.0
Irish Cobbler	do	10.3	3.5	29.3	12.3	25.3	12.7	------	------	53.2	16.0
Do	Early, 1926	37.7	12.5	------	------	91.8	12.7	110.1	11.8	95.7	11.4
Triumph	do	15.8	9.5	------	------	44.2	12.9	50.6	15.9	84.4	9.7
Green Mountain	Late, 1926	115.0	6.9	------	------	129.6	11.6	153.3	10.4	132.5	8.5
Irish Cobbler	do	12[illegible].8	8.8	------	------	121.6	20.9	------	------	134.1	9.8
Triumph	do	60.0	9.8	------	------	90.6	20.9	107.0	16.8	98.9	10.8

It is probable that the favorable condition for germinating and the early growing conditions are more important in determining the yield from seed injured from freezing than from normal seed. Under unfavorable growing conditions it is probable that the young sprouts depend more upon the seed piece for nourishment; if the tissue of the pieces is injured they will tend to decay quickly, and the new sprouts will perish if they have not developed far enough to draw sufficient nourishment from the soil.

TABLE 3.—*Germination and yield per hill of prime potatoes obtained from frozen seed potatoes at Arlington Experiment Farm, 1924–1926*

Variety	Crop	Degree of freezing injury								Check	
		Bad		Medium		Slight		None			
		Germination	Yield	Germination	Yield	Germination	Yield	Germination	Yield	Germination	Yield
		P. ct.	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*	*P. ct.*	*Oz.*
Irish Cobbler	Early, 1925	21.7	6.1	61.5	4.5	56.0	5.4	------	------	99.1	6.5
Triumph	do	8.1	2.7	9.7	1.6	11.2	1.4	------	------	99.3	3.0
Green Mountain	Late, 1925	8.2	11.4	25.0	4.0	32.8	9.3	34.9	13.0	91.3	7.0
Irish Cobbler	do	16.4	5.3	37.9	6.4	29.4	7.2	------	------	90.6	5.4
Green Mountain	Early, 1926	44.0	1.8	------	------	65.5	1.8	63.8	1.9	84.2	2.2
Irish Cobbler	do	37.9	8.2	------	------	63.2	9.0	87.1	10.0	84.0	9.5
Triumph	do	33.6	3.8	------	------	66.8	5.4	85.3	5.0	87.1	8.5
Green Mountain	Late, 1926	75.9	12.5	------	------	94.8	11.2	99.6	13.0	98.8	11.0
Irish Cobbler	do	81.8	12.3	------	------	92.0	11.0	------	------	99.6	11.2
Triumph	do	75.0	6.6	------	------	91.4	8.2	95.8	9.3	94.9	9.0

A theoretical explanation will have to suffice to account for the presence of potatoes showing no injury after the rather severe exposure described and for the slightly larger average yield and greater vitality of these potatoes. It is possible that these individuals were somewhat more resistant to freezing than the average. Data [5] already published show that potatoes develop symptoms of freezing injury in as short a period as one-half minute after actual freezing begins.

[5] WRIGHT, R. C., and DIEHL, H. C. Op. cit.

It is concluded, then, that the potatoes showing no injury did not actually freeze, although most of the surrounding ones showed various degrees of injury from very slight to being frozen to death. It further seems possible that other qualities exist to a greater degree in these resistant individuals, rendering them slightly more productive under certain conditions than the average. The greater vitality, as indicated by larger and more vigorous plants, was marked throughout the growing seasons from the time the plants appeared above the soil until maturity.

Table 3 shows a greater yield per hill from no-injury stock over the checks in all but one case, although the average hill had no more growing space and the average percentage of germination of this stock was practically the same as that of the check, if not slightly greater. Some of this difference may be attributed to the thin transverse slice sufficiently deep to expose all tissue across the stem end being cut from each exposed tuber in order to examine the degree of injury. Although this slice was not cut from the checks or unexposed tubers and no eyes were cut off in making the examination, it is possible that in cutting seed pieces of equal size some of those having ends sliced may have had an additional eye included on certain seed pieces, which might account for some difference in the yield. All the results obtained at the Arlington farm are shown in Figure 1. In Figures 2, 3, and 4 are illustrated the various stages of freezing injury in potatoes described as no injury, slight, and bad. Figure 5 is from a photograph taken in the field, showing the difference in the appearance of plants from frozen seed.

CONCLUSION

From the results presented herewith it seems probable that under certain conditions seed stock known to have been more or less frozen can be used if properly handled. Assuming that an effort is to be made to utilize all usable material, it is evident that as soon as a lot of frozen potatoes is well thawed the first procedure should be to discard all soft or wet tubers in the entire lot, for these have been frozen to death and will quickly decay and contaminate the surrounding potatoes. If the remaining potatoes are to be stored for any considerable time, a second inspection would be advisable to eliminate any specimens in which the decay has developed more slowly than in those first removed. As soon as convenient the potatoes saved from the previous inspections should be inspected by cutting off a thin transverse slice sufficiently deep to expose all tissue across the stem end of each tuber, or, if preferable, by cutting each tuber in half. Those showing extensive blackening or discoloration of the freshly cut tissue and those that may appear normal but have a rather cheesy texture and sour odor when cut should be discarded as being undesirable, and the remainder may be put back into storage until needed for planting. In this way the quantity of undesirable seed stock can be determined, in order that it may be replaced by new stock. If desirable, however, after eliminating the soft and wet specimens, the sound stock can be left in suitable storage until planting time, when those individuals showing serious internal discoloration may be discarded when the seed pieces are cut for planting.

SUMMARY

Potatoes treated as described in these experiments and showing considerable blackening or discoloration of the freshly cut tissue gave so poor a stand as to render them economically unfit for seed purposes, although the yield per hill was comparatively good.

Tubers showing slight freezing—that is, injury caused by or accompanying the crystallization of water in the tubers—proved suitable for seed.

An increased vitality and yield was indicated in certain potatoes that showed no indication of freezing injury after being exposed to temperatures that caused marked injury to other tubers of the same lot. Whether this is due to the elimination of tubers of low vitality by freezing or to some stimulation of the growth processes was not determined. This point deserves further investigation.

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