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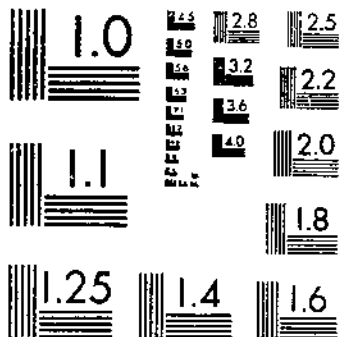
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COMPARATIVE INFLUENCE OF DIFFERENT STORAGE TEMPERATURES ON HEIGHT

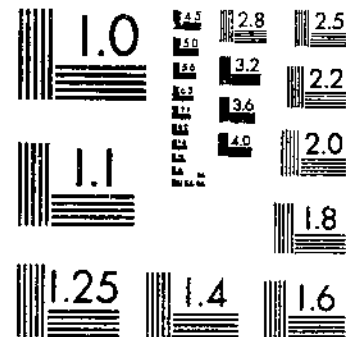
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UNITED STATES DEPARTMENT OF AGRICULTURE
 WASHINGTON, D. C.

COMPARATIVE INFLUENCE OF DIFFERENT STORAGE TEMPERATURES ON WEIGHT LOSSES AND VITALITY OF SEED POTATOES.

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INTRODUCTION

One of the questions most frequently asked regarding the storage of potatoes is what temperature it is most desirable to maintain in the storage house. Until recently little scientific study of this question had been made. It is true that many growers and potato dealers had very definite ideas relative to the best temperature, but they were not based on careful experimental data. In order to ascertain some of the facts concerning the comparative keeping qualities of potatoes when subjected to various temperatures, the Bureau of Plant Industry, United States Department of Agriculture, undertook a study of the subject during the winters of 1918 to 1924, inclusive. The original purpose of this study was to determine the proportion of shrinkage during a full storage period and throughout two full storage periods, or approximately 18 months. It was also intended to throw some light on the inhibition of germination.

Three rooms were used in the cold-storage house at the Arlington Experiment Farm, Rosslyn, Va. One was held as near 32° F. as possible, another at 36°, and a third at 40°. It was found that dormancy of the tubers could be maintained indefinitely at temperatures of 36° or below, but that at 40° some germination was almost certain to occur if the storage period was prolonged much beyond April 15.

¹ The writers wish to acknowledge their indebtedness to the Murbis Laboratory (Inc.), Canton, Pa., for furnishing storage facilities, as well as the services of Malcolm E. Smith in taking temperatures and humidity records and making most of the weighings of the stored material.

JUL 1929

LOSSES IN WEIGHT OF POTATOES IN STORAGE

The shrinkage involved in storing potatoes from fall until the following spring is of considerable economic importance to both the grower and the dealer. This loss in weight usually ranges from 4 to 20 per cent but under exceptionally poor conditions may reach 25 to 30 per cent. As such excessive loss is generally due to several factors, such as field frost, late blight, or other tuber rots, in many of the data relative to storage-house shrinkage no attempt has been made to distinguish moisture and carbon dioxide losses from those caused by decay or by mechanical injuries resulting from the harvesting and storing of the crop.

PREVIOUS INVESTIGATIONS

French and German investigators have published very interesting data on the subject of storage losses. As early as 1865 Nobbe (7)² reported the results of experimental studies concerning the loss of water and carbon-dioxide gas from potato tubers in storage between December 12 and June 7. Unfortunately, these studies were based on but two selected tubers under each set of conditions tested. His experiment embodied eight separate combinations of three factors, namely, temperature, moisture, and light, in which comparisons were made regarding the loss in weight of different lots of tubers stored (1) in a cool, dry, lighted space; (2) in a cool, moist, light room; (3) in a cool, dry, dark room; and (4) in a cool, moist, dark place. Similar comparisons were made in a warm room. The decrease in weight was as follows:

	Grams
(1) Cool (50° to 61° F.), dry, light.....	34.05
(2) Warm (77° to 95° F.), dry, light.....	57.25
(3) Cool (50° to 61° F.), moist, light.....	20.15
(4) Warm (77° to 95° F.), moist, light.....	57.65
(5) Cool (50° to 61° F.), dry, dark.....	34.45
(6) Warm (77° to 95° F.), dry, dark.....	63.25
(7) Cool (50° to 61° F.), moist, dark.....	13.35
(8) Warm (77° to 95° F.), moist, dark.....	62.10

As might be expected, the smallest loss occurred in potatoes stored in a cool, moist, dark place, and the heaviest loss occurred in those held in a warm, dry, dark room. Unfortunately, Nobbe neglected to mention the original weight of the tubers stored under each set of conditions; it is necessary, therefore, to assume that the weight of those stored under each set of storage conditions was identical.

A careful analysis of the temperature, moisture, and light factors involved in Nobbe's experiment would seem to indicate that the first was the most important of the three. For example, if the four sets of data from the cool and the warm chambers at each temperature are added together, the loss in weight from the cool chambers totals 102 grams as against 240.25 grams from the warm chambers. A similar comparison of the humidity shows a loss of 153.25 grams from the moist chamber as compared with 189 grams from the dry one. As the effect of light is found to be practically nil, the two significant factors therefore are temperature and moisture, and in view of the fact that Nobbe does not indicate the degree of humidity maintained or the vapor deficit, it would be unwise to assume that temperature was more important than moisture. According to Nobbe's figures, the ratio of gas to water is 1 to 35.

² Italic numbers in parentheses refer to "Literature cited," p. 17.

In the Agricultural Calendar for 1891, by Mentzel and Lengerke (6, p. 161), data relative to the decrease in weight of 100 kilograms of potato tubers in storage are given, but no statement is made regarding the source. The observations reported extend from the first of November to the end of June, the percentage of loss in weight being given by months as follows:

	Per cent
November.....	0.56
December.....	2.56
January.....	1.00
February.....	1.20
March.....	1.06
April.....	1.40
May.....	2.00
June.....	7.00
Total loss.....	16.98

In 1891 Wolny (10, p. 291) published the results of studies made on 100 selected tubers of 12 varieties of potatoes placed in containers and stored in a dry, deep cellar in which the proper light and a nearly constant temperature (43° to 45° F.) were maintained. Weighings were made on the 1st and 15th of each month. The average loss for the whole period was 6.17 per cent. The losses from the individual varieties varied from 4.55 to 8.48 per cent.

Denaiffe's (3) investigations included eight varieties on which he studied the decrease in weight from December 1, 1904, to June 1, 1905. One hundred kilograms of each variety was used. The average loss from these varieties during the 6-month period was 7 per cent, the losses varying from 5 per cent in Up-to-Date to 9.5 per cent in Royal Kidney. Taft and Hedrick (9) report a loss of 5 per cent in weight in a barrel of potatoes stored in a basement cellar from September 30 to March 28, and of 6.5 per cent from March 28 to May 1, or a total loss of 11.5 per cent.

Studies by Fraser (4) on the decrease in weight of Sir Walter Raleigh and Carman No. 3 tubers stored in crates in a cool cellar from November 6, 1903, to April 27, 1904, showed a loss of 12 per cent in the former and of 10 per cent in the latter.

Studies by Butler (1) on the relation of temperature to loss in weight of Green Mountain potatoes placed in storage November 12 show the percentages of loss stated in Table I and corroborate Nobbe's (7) results regarding the relation of temperature to loss of weight.

TABLE 1.—Loss of weight by Green Mountain potatoes in storage, as recorded by Butler

Storage temperature	Loss at stated intervals				
	30 days	60 days	90 days	120 days	150 days
° F.	Per cent	Per cent	Per cent	Per cent	Per cent
39.....	0.58	1.43	1.43	2.26	2.58
48.....	1.26	2.53	3.37	4.21	7.18
60.....	1.52	2.77	4.01	6.65	11.56

Butler also made a comparative study of the respiration and transpiration losses from two lots of Green Mountain potatoes removed January 26 from ordinary storage and subjected to a tem-

perature of 50° F., one lot being exposed to free circulation of air and the other being stored in dead air. At the end of 90 days it was found that the lot exposed to free air had decreased 8.96 per cent in weight, whereas the other lot showed a decrease of only 1.35 per cent. At the end of 119 days the percentages of loss were 17.24 and 2.79, respectively. It was also found that those exposed to free air germinated in 43 days, whereas those in dead air remained dormant.

The effect of tuber-wound injuries in relation to moisture loss in storage reported by Butler (2) indicates a greater shrinkage from injured than from uninjured stock. It was further found that a longer period was required to repair the injury when the potatoes were stored at from 46.4° to 50° F. than when they were stored at 68° for a short period and then placed in the lower temperature.

In studies on the loss of moisture, conducted at the Marble Laboratory (3, p. 33), Canton, Pa., observations were made on immature Russet Rurals from December 1, 1924, to May 1, 1925, a term of 151 days. These studies involved the relation of ventilation or air circulation to moisture and carbon dioxide losses. Equal numbers of tubers of the same weight were placed in each of 12 desiccators. The rate of air change varied from one change in 24 hours to four changes an hour, effected by an air-suction line connected with the desiccators. The air passing through the desiccators was first drawn through calcium-chloride tubes to remove the moisture; the air drawn from the desiccators was also passed through calcium-chloride tubes, and the moisture so removed was determined by reweighing the tubers. The weight losses from the tubers are given for two periods of time, December 1, 1924, to February 18, 1925, and the total period December 1, 1924, to May 1, 1925, because the disturbing factor of germination, with its accompanying chemical and physiological activities, began about February 18.

These data, as presented in Table 2, indicate that loss in weight up to the time of germination was proportional to the number of air changes. It is apparent, therefore, that excessive ventilation is undesirable from the standpoint of maintenance of weight.

TABLE 2.—*Transpiration and respiration losses from 4 kilograms of potatoes under varying degrees of aeration at the Marble Laboratory from December 1, 1924, to May 1, 1925*

Frequency of air change	Loss in weight from—			
	Dec. 30, 1924, to Feb. 18, 1925		Dec. 1, 1924, to May 1, 1925	
	Grams	Per cent	Grams	Per cent
Once in 24 hours.....	32.07	0.80	65.76	1.64
Once in 12 hours.....	50.97	1.27	122.70	3.07
Once in 6 hours.....	88.47	2.21	197.02	4.92
Once an hour.....	124.06	3.12	306.30	7.16
Twice an hour.....	157.55	3.94	486.90	12.17
Three times an hour.....	197.84	4.95	562.23	14.05
Four times an hour.....	229.73	5.74	631.45	15.79

In potato-respiration studies by Kimbrough (5) it was observed that the rate of respiration was high immediately after digging, but that when equilibrium was reached it remained constant throughout a

storage period of 100 days. The removal of potatoes from a low to a high temperature resulted in an immediate acceleration of respiration much beyond that in tubers continuously stored at the higher temperature.

DEPARTMENT OF AGRICULTURE STUDIES

In 1920 preliminary storage studies were undertaken by the Office of Horticulture, Bureau of Plant Industry, for the purpose of determining the relative losses from potatoes stored in a modern cold-storage plant at 32°, 36°, and 40° F., respectively, and the effect of these temperatures on the vigor of the seed stock. The Irish Cobbler and Gold Coin varieties were selected for study, and the tubers were stored in barrels. Some of the barrels put into storage in the fall of 1920 were held through two storage periods. The data submitted in Table 3 represent the losses due to transpiration and respiration, together with those occasioned by germination and decay.

TABLE 3.—Losses in weight and percentage of decay of Gold Coin and Irish Cobbler tubers held in storage at Arlington Experiment Farm from November 26, 1920, to April 20, 1922

Variety	Storage temperature	Weight of tubers on—		Loss in weight	Tubers remaining sound	Tubers decayed
		Nov. 26, 1920	Apr. 20, 1922			
	° F.	Pounds	Pounds	Per cent	Per cent	Per cent
Gold Coin	32	177.5	151.75	14.5	11.5	88.5
	36	181.0	153.5	15.2	51.5	48.5
	40	153.5	139.0	9.4	93.8	3.2
Irish Cobbler	32	181.0	157.5	13.0	27.6	72.4
	40	180.25	157.25	12.8	95.9	4.1

It will be observed that the period of storage extended from November 26, 1920, to April 20, 1922, or 510 days. A barrel of Gold Coin was held in each of the three storage rooms throughout the whole period, while the Irish Cobbler was carried only in the 32° and 40° F. rooms. The weight losses from the Gold Coin stock were slightly greater in the 36° F. room than in 32°, and both were considerably in excess of that at 40°. The most interesting feature of the data was the condition of the stock when removed from storage as judged by the percentage by weight of sound and decayed tubers. For example, Gold Coin stock held at 32° showed only 11.5 per cent (fig. 1) sound tubers, whereas that held at 36° showed 51.5 per cent (fig. 2) and that at 40°, 96 per cent (fig. 3). Very similar results were obtained with Irish Cobbler, in which the percentage of sound tubers at 32° was 27.6 and at 40°, 95.9 per cent. (Figs. 4 and 5.)

The decay of the tubers is not assumed to be primarily attributable to fungous or bacterial infection but rather to a general breaking down of cell tissue as a result of the death of their protoplasmic contents. It is probably true that when such breaking down occurred one or more of the bacterial soft-rot organisms invaded the tissue and completed the decomposition of the tuber.

In 1921, 3 barrels of the Irish Cobbler variety and 2 of the Green Mountain were stored at each of the three temperatures. The mate-

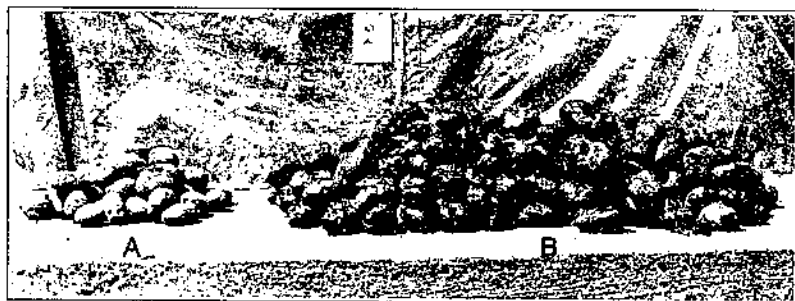


FIGURE 1. Gold Coin potatoes stored at 32° F., November 26, 1920. Photographed April 20, 1922. Net weight of tubers when stored, 177.5 pounds; net weight when removed, 151.25 pounds; weight loss, 14.5 per cent. A, Sound tubers, 17.5 pounds; B, decayed tubers, 131.25 pounds.



FIGURE 2. Gold Coin potatoes stored at 36° F., November 26, 1920. Photographed April 20, 1922. Net weight of tubers when stored, 181 pounds; net weight when removed, 153.5 pounds; weight loss, 15.2 per cent. A, Sound tubers, 79 pounds; B, decayed tubers, 71.5 pounds.

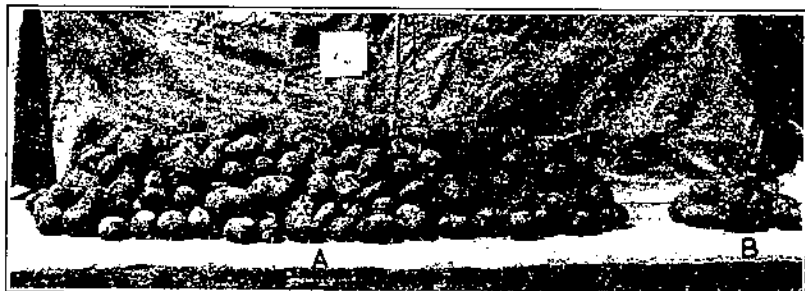


FIGURE 3. Gold Coin potatoes stored at 107° F., November 26, 1920. Photographed April 20, 1922. Net weight of tubers when stored, 153.5 pounds; net weight when removed, 149 pounds; weight loss, 9.4 per cent. A, Sound tubers, 131.5 pounds; B, decayed tubers, 4.5 pounds.



FIGURE 4. Irish Cobbler potatoes stored at 32° F., November 26, 1920. Photographed April 20, 1922. Net weight of tubers when stored, 181 pounds; net weight when removed, 157.5 pounds; weight loss, 13 per cent. A, Sound tubers, 43.5 pounds; B, decayed tubers, 114 pounds.

rial was stored October 24, and weighings were taken January 3, February 20, and April 3, 1922. Owing to other demands for the seed stock, the last weighing, April 3, included only 1 barrel of each, except in the case of Irish Cobbler at 36° F., 2 barrels of which were still intact.

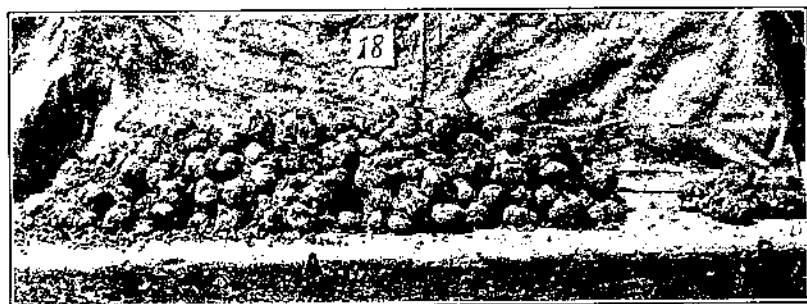


FIGURE 5.—Irish Cobbler potatoes stored at 40° F., November 26, 1920. Photographed April 20, 1922. Net weight when stored, 180.25 pounds; net weight when removed, 157.25 pounds; weight loss, 12.8 per cent. A, Sound tubers, 150.75 pounds; B, decayed tubers, 6.5 pounds

Table 4 gives the percentage of weight lost from the individual barrels and the average loss of the 3 barrels of Irish Cobbler and 2 of Green Mountain up to February 20. These data show that losses in weight were consistently lower in both varieties at 36° than at 32° or 40° F. No satisfactory explanation can be offered for these differences.

TABLE 4.—Losses in weight of Irish Cobbler and Green Mountain tubers at Arlington Experiment Farm, October 24, 1921, to April 3, 1922

Variety and storage temperature		Net weight when stored	Weight Jan. 3, 1922	Loss in weight	Weight Feb. 20, 1922	Loss in weight	Weight Apr. 3, 1922	Loss in weight
		Pounds	Pounds	Per cent	Pounds	Per cent	Pounds	Per cent
Irish Cobbler:								
32° F.	First barrel	178	175	1.68	173.4	2.58		
	Second barrel	175.5	171.5	2.28	170.5	2.05	169.0	3.70
	Third barrel	180.5	177	1.94	175.0	3.04		
	Average loss			1.97		2.89		3.70
36° F.	First barrel	177	176	.57	175.0	1.13	174.8	1.24
	Second barrel	172.5	170	1.45	168.3	1.85	169.3	1.86
	Third barrel	181	179.3	.94	179.2	.99		
	Average loss			.99		1.32		1.55
40° F.	First barrel	174.5	171	2.01	171	2.01		
	Second barrel	173	170.3	1.56	169.3	2.14		
	Third barrel	181.5	177.8	2.03	176.4	2.81	175.3	3.42
	Average loss			1.87		2.32		3.42
Green Mountain:								
32° F.	First barrel	172	166.5	3.20	165.8	3.60		
	Second barrel	174	168	3.44	167	4.02	165.0	4.83
	Average loss			3.32		3.51		4.83
36° F.	First barrel	163.5	166.5	1.19	166.3	1.31		
	Second barrel	174.5	173	.86	172.7	1.03	171.3	1.83
	Average loss			1.03		1.17		1.83
40° F.	First barrel	175	171.3	2.11	167.3	4.40		
	Second barrel	176.5	173.0	1.98	171.0	3.11	169.5	3.70
	Average loss			2.05		3.76		3.70

A comparison of weight losses of potatoes stored at 32° and 40° F. showed less difference in the case of the Irish Cobbler than in that of the Green Mountain, in each instance the loss being greater at 32° than at 40°. The percentage of weight loss from October 24, 1921, to April 3, 1922, in the 32°, 36°, and 40° storage rooms was 3.70, 1.55, and 3.42, respectively, for the Irish Cobbler, and 4.83, 1.83, and 3.79 for the Green Mountain.

In 1924 a comparative test was made of the relative seasonal weight loss of potatoes stored in different types of storage houses and in special fiber boxes instead of barrels. One lot each of Irish Cobbler, Triumph, Green Mountain, and Russet Rural was stored in the Aroostook Farm potato-storage house at Presque Isle, Me.; the second lot was stored at the Marble Laboratory, Canton, Pa., and in the 40° F. room in the cold-storage plant at the Arlington Experiment Farm, Rosslyn, Va. The bank-cellar storage house of the Marble Laboratory was kept at as near 40° as possible, whereas the temperature of the Aroostook Farm potato-storage house varied between 34° and 45° F. Comparisons of data are therefore only possible between the varieties used. The results, as submitted in Table 5, clearly show a smaller percentage of weight loss in all four varieties in the Aroostook Farm storage house.

TABLE 5.—Losses of weight in potatoes stored at Presque Isle, Me., Canton, Pa., and Rosslyn, Va., 1924-25

Variety and locality where stored	Weight Oct. 4, 1924	Weight Apr. 3, 1925	Weight loss	Average loss for each variety
Irish Cobbler:	<i>Pounds</i>	<i>Pounds</i>	<i>Per cent</i>	<i>Per cent</i>
Presque Isle, Me.	214.5	205.8	4.06	5.58
Canton, Pa.	210.0	188.2	5.82	
Rosslyn, Va.	209.0	194.4	6.99	
Triumph:				
Presque Isle, Me.	199.5	194.8	2.36	6.33
Canton, Pa.	202.5	186.2	8.05	
Rosslyn, Va.	199.5	182.4	8.57	
Green Mountain:				
Presque Isle, Me.	214.0	202.8	5.23	6.95
Canton, Pa.	214.0	197.1	7.90	
Rosslyn, Va.	214.0	197.5	7.71	
Russet Rural:				
Presque Isle, Me.	206.0	197.0	4.37	8.59
Canton, Pa.	205.5	183.6	10.66	
Rosslyn, Va.	207.0	184.9	10.68	
Average, four varieties:				
Presque Isle, Me.			4.01	
Canton, Pa.			8.07	
Rosslyn, Va.			8.49	

The average loss in the three storage places of the Irish Cobbler was the lowest, with Triumph, Green Mountain, and Russet Rural following in the order named. The largest individual deviations occurred in the case of the Triumph and Russet Rural stored at Presque Isle, Me., in which the former showed a weight loss of 2.36 per cent as compared with 8.05 at Canton, Pa., and 8.57 at Rosslyn, Va., whereas in the Russet Rural the percentage losses were 4.37, 10.66, and 10.68, respectively. The discrepancy in these two instances in

the Maine data would seem to be in excess of normal, but no satisfactory explanation can be offered.

In summing up the average weight losses of all four varieties under each set of storage conditions, the results show that the percentage of loss in the Aroostook Farm potato storage was only half that at the Marble Laboratory and at the Arlington Experiment Farm, the figures being 4.03, 8.07, and 8.49 per cent, respectively. Although the primary object of this test was to obtain data on the percentage of weight loss, it was thought desirable to obtain yield records from the seed so stored. The significance of the data, which are presented in Table 6, lies in the fact that the stock stored at the Marble Labora-

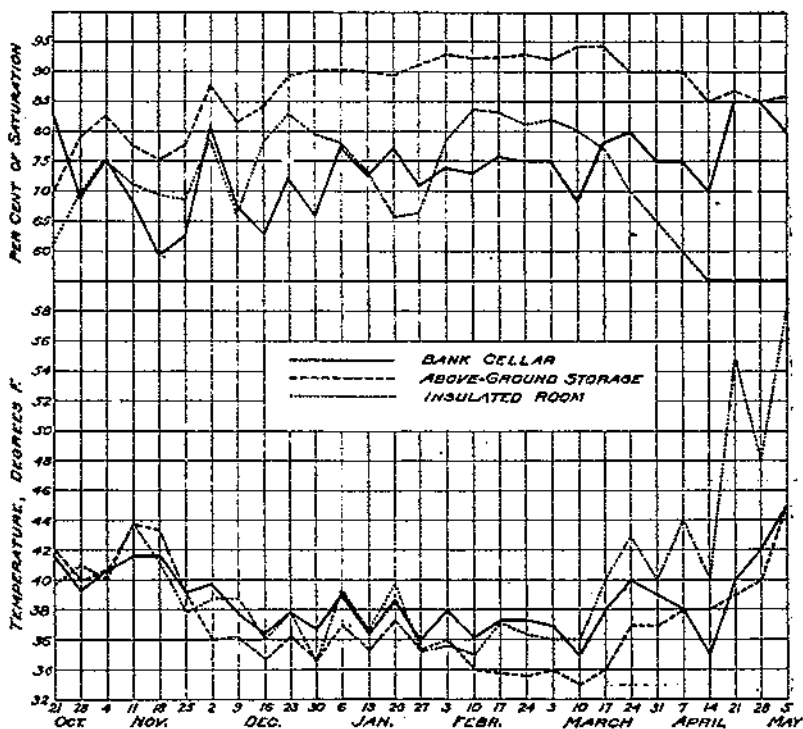


FIGURE 6.—Comparative yield of seed potatoes under various conditions of storage

tory gave consistently higher yields than that stored in the other two storage houses. This is perhaps best emphasized by Figure 6, which graphically expresses the differences in yields.

In the 1925-26 studies of weight loss an attempt was made to get the approximate percentage of loss from the time of harvesting the tubers. The four varieties as used in the 1924-25 studies were selected as soon after digging as possible, care being taken to obtain sound and uninjured tubers. These were packed in the fiber bushel boxes and immediately weighed.

These studies were conducted at the Marble Laboratory under three types of storage conditions. The first, referred to in Table 7 as A, was an above ground storage house especially constructed for

TABLE 6.—Comparative average yield of Irish Cobbler, Triumph, Green Mountain, and Russet Rural seed potatoes grown at Aroostook Farm, Presque Isle, Me., and stored in fiber boxes at the Arlington Experiment Farm, Rosslyn, Va.; Marble Laboratory, Canton, Pa.; and Aroostook Farm, seasons of 1924 and 1925

Variety and locality in which seed potatoes were stored	Row planted	Average yield per row ¹			Average yield per acre		
		Primes	Culls	Total	Primes	Culls	Total
		Number	Pounds	Pounds	Pounds	Bushels	Bushels
Irish Cobbler:							
Arlington Experiment Farm.....	10	146.0	18.7	164.7	243.3	31.2	274.5
Marble Laboratory.....	7	172.7	19.9	192.6	287.8	33.1	321.0
Aroostook Farm.....	10	152.7	14.7	167.4	254.5	24.5	279.0
Triumph:							
Arlington Experiment Farm.....	10	148.1	10.8	158.9	248.8	18.0	266.8
Marble Laboratory.....	7	157.4	10.4	167.8	252.3	17.3	270.0
Aroostook Farm.....	10	138.4	5.7	144.1	230.7	9.5	240.2
Green Mountain:							
Arlington Experiment Farm.....	10	160.6	12.4	173.0	267.7	20.7	288.4
Marble Laboratory.....	10	167.8	9.9	177.7	279.7	16.5	296.2
Aroostook Farm.....	10	150.3	11.5	167.8	230.5	19.2	279.7
Russet Rural:							
Arlington Experiment Farm.....	8	147.1	16.6	163.7	245.2	27.7	272.9
Marble Laboratory.....	9	167.9	12.8	180.8	279.8	21.5	301.3
Aroostook Farm.....	9	164.8	8.3	173.1	273.8	13.8	287.6
Average of four varieties:							
Arlington Experiment Farm.....		150.5	14.6	165.1	250.8	24.4	275.2
Marble Laboratory.....		165.5	13.2	178.7	277.4	22.1	299.5
Aroostook Farm.....		152.9	10.1	163.0	254.9	16.7	271.6

¹ Each row=0.01 acre.

TABLE 7.—Losses of weight of potatoes held under different storage conditions at the Marble Laboratory, Canton, Pa., 1925-26

[A—Aboveground storage, B—insulated room, C—bank-cellar storage]

Variety and type of storage	Net weight and loss at different dates during storage period												
	Oct. 24, 1925		Dec. 21, 1925		Jan. 28, 1926		Mar. 4, 1926		May 3, 1926		Average weight loss		
	Weight	Weight loss	Weight	Weight loss	Weight	Weight loss	Weight	Weight loss	Weight	Weight loss			
Irish Cobbler:													
A.....	Lbs. 183.9	Lbs. 162.5	P. ct. 0.85	Lbs. 160.8	P. ct. 1.89	Lbs. 160.8	P. ct. 2.01	Lbs. 160.8	P. ct. 2.01	Lbs. 159.9	P. ct. 2.44	3.38	
B.....	212.9	211.5	.69	208.6	2.02	207.6	2.49	207.0	2.77	204.4	3.99		
C.....	159.4	158.4	.63	153.8	2.26	155.0	2.76	154.6	3.01	153.5	3.70		
Triumph:													
A.....	155.0	154.2	1.09	152.2	2.37	151.0	2.50	151.8	2.83	151.3	3.95	4.15	
B.....	153.1	153.8	.84	150.9	2.90	149.7	3.48	149.3	3.74	147.2	5.06		
C.....	154.6	153.2	.91	150.2	2.85	149.5	3.39	149.0	3.62	147.9	4.40		
Green Mountain:													
A.....	222.2	220.2	.90	218.8	2.43	216.5	2.56	216.3	2.66	215.6	2.97	4.17	
B.....	219.2	217.6	.73	213.4	2.65	212.0	3.28	211.3	3.60	207.8	5.20		
C.....	219.2	217.4	.82	213.1	2.78	212.1	3.24	211.3	3.60	209.7	4.33		
Russet Rural:													
A.....	217.4	215.1	1.08	211.2	2.85	210.5	3.17	210.2	3.31	208.8	3.96	5.47	
B.....	161.0	160.5	.86	156.6	3.28	155.4	4.01	154.6	4.51	151.3	6.35		
C.....	162.9	161.4	.92	156.9	3.68	153.8	4.36	153.0	4.85	153.3	5.89		
Average of 4 varieties:													
A.....	169.9	168.0	1.00	165.3	2.42	164.9	2.63	164.7	2.74	163.9	3.16	4.28	
B.....	167.3	165.9	.75	162.5	2.67	161.2	3.26	160.6	3.58	157.7	5.13		
C.....	174.0	172.6	.80	169.0	2.87	168.1	3.39	167.5	3.74	166.1	4.54		

apple storage; the second type, designated as B, was a cork-insulated room on the second floor above the bank-cellar room, called C. Four 1-bushel boxes of each variety were stored in each type of room, making a total of 16 boxes in each room. Weights were taken October 24 and December 21, 1925, and January 28, March 4, and May 3, 1926. The percentage of weight loss occurring between October 1 to 4, when the potatoes were harvested and put up, and October 24 is supposed to represent the initial transpiration and respiration losses occurring during transit. As will be noted, these losses are relatively small, varying from 0.63 to 1.09 per cent. The data indicate that some varieties lose more weight in storage than others. It also suggests that the shrinkage due to respiration and transpiration is directly correlated with the ripeness of the tubers when harvested. Russet Rural tubers, being the least mature, show the greatest loss in weight.

Another interesting point brought out in the data is that the tubers stored in the aboveground storage house (A) showed consistently lower weight loss. It is also apparent that up to March 4, at least,

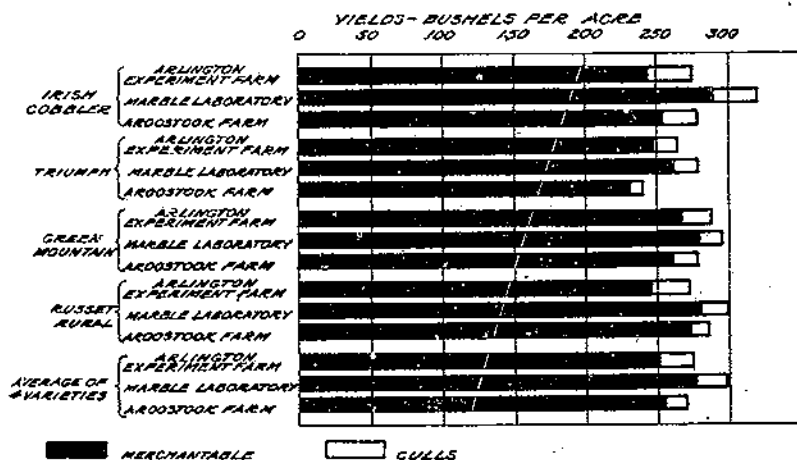


FIGURE 7.—Relative humidity and temperature variations in three types of potato storage at the Marble Laboratory, Canton, Pa., 1925-26

there was only a slight difference in the percentage of loss from tubers stored in B and C storage rooms. The reason for the greater weight shrinkage especially in the insulated room is at once apparent from a study of Figure 7, which shows that the percentage of air saturation (humidity) in A was much higher than in B and C, and also that the temperature with but two exceptions was consistently lower in A than in B and C from about November 28 to May 5. It is therefore apparent that conditions in storage A were more favorable to the slowing up of respiration and transpiration losses than in rooms B and C.

The B storage room had a lower humidity and a higher temperature, whereas in the A house the temperature was lower and the humidity relatively higher. Ordinarily it might be assumed that the shrinkage of potatoes stored in the bank-cellar storage room (C) would be less than that of potatoes in the aboveground storage house (A). The explanation for this occurrence is that when severe cold weather

set in it was necessary to close all ventilators in A to prevent frost injury, with the result that the air became more or less completely saturated with moisture given off by the potatoes and apples stored therein. The temperature also dropped lower during this period.

Further explanation of the difference in the behavior of potatoes stored under A and C conditions may be found in the fact that in the storage cellar the wall opposite the bank adjoined a heated room, and it was necessary to introduce a larger volume of outside cold air into the storage room than would otherwise have been the case, and consequently transpiration losses increased.

INFLUENCE OF STORAGE TEMPERATURES ON VITALITY OF POTATOES

In order to determine the effect of different storage temperatures on the vitality of seed potatoes, field studies were conducted at the Virginia Truck Experiment Station, Norfolk, Va.; Arlington Experiment Farm, Rosslyn, Va.; and Aroostook Farm, Presque Isle, Me. The results obtained at each of the three points, although not always in accord, are nevertheless of interest.

VIRGINIA TRUCK EXPERIMENT STATION

The experimental studies at the Virginia Truck Experiment Station,³ Norfolk, Va., were conducted during 1920, 1921, and 1922 with the Irish Cobbler variety. The planting dates for the three years were March 18, March 2, and March 17; the harvesting dates were July 8-9, July 21-22, and July 10-11, respectively. The yield data as presented in Table 8 indicate an increase of primes from the seed stored at 36° F. in 1920 and 1921 over the number of primes from seed stored at 32°. The yield of primes from the seed stored at 40° was less in 1920 and 1922 than from the seed stored at 32°.

TABLE 8.—Comparative influence of different storage temperatures on the yield of Irish Cobbler potatoes grown at the Virginia Truck Experiment Station, Norfolk, Va., 1920-1922

Year	Storage temperature	Rows ¹ planted	Average yield per row ¹			Average yield per acre		
			Primes	Culls	Total	Primes	Culls	Total
	° F.	Number	Pounds	Pounds	Pounds	Bushels	Bushels	Bushels
1920	32	10	105.6	33.5	139.1	176.0	55.8	231.8
	36	12	109.6	30.8	140.4	182.7	51.3	234.0
	40	11	100.0	35.3	135.3	168.7	58.8	227.5
1921	32	8	128.6	36.8	165.4	214.3	61.3	275.6
	36	8	141.7	31.8	173.5	236.2	53.0	289.2
	40	8	142.1	29.3	171.4	236.8	48.8	285.6
1922	32	8	92.5	29.1	121.6	154.2	48.5	202.7
	36	8	63.8	29.8	93.4	106.0	49.7	155.7
	40	8	82.8	24.7	107.5	138.0	41.2	179.2
Three-year average	32		108.9	33.1	142.0	181.5	55.2	236.7
	36		105.0	30.8	135.8	175.0	51.3	226.3
	40		108.3	29.8	138.1	180.5	49.6	230.1

¹ Each row = 0.01 acre.

In 1922 the yield in primes from the 36° seed was unaccountably low. Unfortunately, no unusual condition was observed in 1922 which might account for this low yield. As a result of this condition the

³ The writers wish to acknowledge their indebtedness to the Virginia Truck Experiment Station for providing facilities for the use of land and equipment necessary to the growing and harvesting of the crop.

3-year average yield from the 36° seed plot is lower than it should have been. The variations in yield from the three lots of seed are not sufficiently marked to justify any claim of superiority of one over the others. Such increases as are noted could very appropriately be attributed to inequalities in soil moisture or soil fertility or a combination of both.

ARLINGTON EXPERIMENT FARM

The studies conducted with Irish Cobbler potatoes at the Arlington Experiment Farm extended from 1919 to 1924, inclusive, but owing to incomplete data, the results for 1920 are not included. These studies embraced spring and fall crops.

The data given in Table 9 indicate, as might be expected in this section of the country, wide variations in yield from year to year and no consistent superiority of any of the three lots of seed.

TABLE 9.—Comparative influence of different storage temperatures on the yield of Irish Cobbler potatoes grown at the Arlington Experiment Farm during 1919 and 1921-1924.

Crop and year	Storage temperature	Rows planted	Average yield per row ¹			Average yield per acre		
			Primes	Culls	Total	Primes	Culls	Total
Spring crop:	° F.	Number	Pounds	Pounds	Pounds	Bushels	Bushels	Bushels
1919	32	1 and 7	133.1	36.3	169.4	221.8	60.5	282.3
	36	2 and 3	131.8	32.4	164.2	219.7	54.0	273.7
	40	3 and 9	130.4	34.5	164.9	217.3	57.5	274.8
1921	32	8	45.9	47.2	93.1	76.5	78.7	155.2
	36	8	36.8	52.3	89.1	61.3	87.2	148.5
	40	8	38.6	43.9	82.5	64.3	73.2	137.5
1922	32	8	107.0	37.4	144.4	173.3	62.3	240.6
	36	8	132.2	34.7	166.9	220.3	57.8	278.1
	40	8	97.7	27.5	125.2	162.8	46.8	208.6
1923	32	20	70.1	24.9	95.0	116.3	41.5	168.3
	36	20	75.4	27.0	102.4	125.6	44.9	170.8
	40	20	85.3	24.9	110.2	142.1	41.4	183.5
Fall crop:								
1923	32	4	75.5	33.5	109.0	128.8	55.8	181.6
	36	4	66.6	30.3	97.4	111.0	51.3	162.3
	40	4	65.4	26.7	92.1	109.0	44.5	163.5
1924	32	4	71.1	9.4	80.5	118.6	15.7	134.2
	36	4	80.3	14.0	94.3	133.8	23.3	157.1
	40	4	80.4	11.1	91.5	134.0	18.5	152.5
Average 1919, 1921-1924	32	-----	83.8	31.5	115.3	139.7	52.9	192.2
	36	-----	87.2	31.9	119.1	145.3	53.1	198.5
	40	-----	82.9	28.1	111.0	138.2	46.8	185.0

¹ Each row=0.01 acre.

The average yield of the six crops stored at 32°, 36°, and 40° F. shows a gain of 13.5 bushels in total acre yield and 7.1 bushels of primes in favor of the 36° F. seed over that from the seed stored at 40° F. A comparison of the yields from the 32° and 36° F. stored seed shows a total increase in acre yield in favor of the 36° seed of 6.3 bushels and in primes of 5.6 bushels. These differences are hardly sufficient to be regarded as significant.

A similar study was conducted at the Arlington Experiment Farm during 1919, 1921, 1923, and 1924 with the Green Mountain variety. The results from this study as presented in Table 9 show the same

yearly fluctuations in yields, but they are more consistent in the comparative yields from seed stock stored at the three temperatures. With the exception of 1921, the tubers stored at 36° and 40° F. gave the largest yields. A study of the average yield for the 4-year period shows a fairly good increase from the 36° and 40° seed tubers over those stored at 32°, the total average yield being 164 bushels an acre from tubers stored at 32° and 181.4 bushels and 189.2 bushels, respectively, from the tubers stored at 36° and 40°. The acre yield of primes was about in the same ratio, 129.2, 143.8, and 146.9 bushels, respectively. Whether these differences in yield of the Green Mountain variety are owing to increased sensitiveness to low storage temperature when prolonged to midsummer, it is impossible to say.

TABLE 10.—Comparative influence of different storage temperatures on the yield of Green Mountain potatoes grown as a fall crop at the Arlington Experiment Farm, during 1919, 1921, 1923, and 1924

Season	Storage temperature	Rows ¹ planted	Average yield per row ¹			Average yield per acre			
			Primes	Culls	Total	Primes	Culls	Total	
	° F.	Number	Pounds	Pounds	Pounds	Bushels	Bushels	Bushels	
1919	32	3	122.1	29.8	151.9	203.5	49.7	253.2	
	46	3	133.6	35.1	169.7	222.7	60.1	282.7	
	40	3	130.3	37.1	167.4	217.1	61.8	278.9	
1921	32	5	63.1	26.9	90.0	105.2	44.8	150.0	
	36	5	58.5	23.5	82.0	97.5	39.2	136.7	
	40	5	58.7	25.7	85.4	97.8	44.5	142.3	
1923	32	4	39.1	11.1	50.2	65.2	18.5	83.7	
	36	4	41.0	14.7	55.7	68.3	24.5	92.8	
	40	4	52.9	22.8	75.7	88.2	38.0	126.2	
1924	32	15	85.8	15.8	101.6	143.0	26.3	169.3	
	36	15	112.1	16.0	128.1	186.8	29.7	216.5	
	40	15	110.7	15.0	125.7	184.5	26.0	209.5	
Average 1919, 1921, 1923, and 1924.		32	27	77.5	20.9	98.4	129.2	34.8	164.0
		36	27	65.3	22.6	108.9	143.8	37.6	181.4
		40	27	88.2	25.4	113.6 ²	146.9	42.3	189.2

¹ Each row=0.01 acre.

In connection with the 1921 spring-crop studies on the influence of temperature on seed as expressed in the resultant crop, a portion of the seed from each of the three storage temperatures was removed 12 days before being planted and placed in an adjoining room in which the temperature was approximately 70° F. This was done for the purpose of determining whether such exposure of the seed would eliminate delayed germination of the seed stock when planted direct from storage. It had been previously observed that stock planted direct from 32° storage was slower in emerging than that from 36° storage and diverged still more widely from that from the 40° room. In the comparison of yields between seed taken direct from storage and that exposed to a higher temperature for 12 days it was not expected that aside from delayed emergence of the plants there would be any material difference in yields; but in compiling the data it became evident that in the case of the seed from two out of the three storages, namely, that from the 32° storage and that from the 40° storage, the increase in yield was large enough to be significant. For

some as yet inexplicable reason the lot from the 36° room which had been exposed to the higher temperature showed a slight decrease in yield as compared with the lot planted direct from storage. The complete data are presented in Table 11.

TABLE 11.—Comparative yields from Irish Cobbler seed potatoes subjected to 12 days' exposure at 70° F., and those planted direct from cold storage at the Arlington Experiment Farm in 1921

Storage temperature	Planted direct from storage or after 12 days	Average yield per row ¹			Average yield per acre			Gain (+) or loss (-) as compared to direct planting	
		Primes	Culls	Total	Primes	Culls	Total	Primes	Total
		<i>Pounds</i>	<i>Pounds</i>	<i>Pounds</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Bushels</i>	<i>Per cent</i>	<i>Per cent</i>
32° F.	Direct	35.4	45.8	81.2	59.0	76.3	135.3		
	After 12 days	56.5	48.6	105.1	94.2	81.0	175.2	+59.6	+29.4
36° F.	Direct	37.3	53.0	90.3	62.2	98.3	150.5		
	After 12 days	38.3	51.6	87.9	60.5	86.0	146.5	-2.8	-2.7
40° F.	Direct	34.6	40.7	75.3	57.7	67.8	125.5		
	After 12 days	42.6	47.1	89.7	71.0	78.5	149.5	+23.1	+19.1
Average of 3 temperatures.	Direct	35.8	46.5	82.3	59.6	77.5	137.1		
	After 12 days	45.1	49.1	94.2	75.2	81.8	157.0	+28.0	+14.5

¹ Each row = 0.01 acre.

AROOSTOOK FARM

Although a study of the comparative effect of different storage temperatures on the vitality of seed potatoes was conducted at Aroostook Farm, Presque Isle, Me., during 1919, 1920, 1921, and 1922, the data for the first two seasons are too incomplete to be of value. Accordingly the data in Tables 11 and 12 are based on results obtained in 1921 and 1922 from the Irish Cobbler and Green Mountain varieties.

TABLE 12.—Comparative influence of different storage temperatures on the yield of Irish Cobbler and Green Mountain potatoes grown at Aroostook Farm, Presque Isle, Me., during 1921 and 1922

Season	Storage temperature	Irish Cobbler						Green Mountain					
		Average yield per row ¹			Average yield per acre			Average yield per row ¹			Average yield per acre		
		Primes	Culls	Total	Primes	Culls	Total	Primes	Culls	Total	Primes	Culls	Total
	° F.	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Bush.</i>	<i>Bush.</i>	<i>Bush.</i>
1921	32	107.8	15.2	123.0	179.5	25.4	205.0	187.2	8.4	195.6	311.9	13.9	325.8
	36	120.8	14.5	135.3	201.3	24.2	225.5	183.6	7.9	191.5	306.0	13.2	319.2
	40	115.0	11.2	126.2	191.7	18.7	210.4	181.8	5.8	187.6	303.1	9.6	312.7
1922	32	154.2	35.8	190.0	257.0	59.7	316.7	177.2	28.3	205.5	295.3	47.2	342.5
	36	159.5	28.8	188.3	265.8	48.0	313.8	184.3	28.7	212.0	305.5	47.8	353.3
	40	144.3	31.5	175.8	240.5	52.5	293.0	183.3	25.5	208.8	305.5	42.5	348.0
Average	32	131.0	25.5	156.5	218.3	42.5	260.8	182.2	18.3	200.5	303.7	30.5	334.2
	36	140.2	21.0	161.8	233.6	36.1	269.7	183.5	18.3	201.8	305.6	30.5	336.3
	40	129.7	21.3	151.0	216.2	35.5	251.7	182.6	15.6	198.2	304.2	26.0	330.2

¹ Each row = 0.01 acre.

A review of all the data given fails to indicate any appreciable difference in yield except in the case of the Green Mountain potatoes grown at the Arlington Experiment Farm in 1924, in which case the vitality of the seed stored at 32° F. appeared to have been slightly injured.

SUMMARY

The experimental results herein noted, obtained by previous investigators, indicate the extent of losses in potatoes stored under different storage conditions and for various periods of time. The data cited show that there is a distinct correlation between weight loss and temperature and humidity.

The data obtained from the long-term storage experiment, 1920-1922, indicate the injurious effect on tubers of being subjected to low temperature throughout two normal storage periods. It further shows that when potatoes are stored at a temperature of 40° F. there is very little decay.

Figures 1 to 5 indicate a different response to temperature between the Gold Coin and Irish Cobbler varieties. This difference is particularly apparent in Figures 3 and 5, representing the stage of germination of the two varieties in the 40° F. temperature room. The Gold Coin potato shows slight germination in some of the tubers, whereas all of the Irish Cobbler tubers show an advanced stage of sprout development. In fact, germination has progressed to the point of wilting or softening of the flesh owing to excessive moisture loss.

Different germination responses would doubtless have been obtained in a 40° F. temperature if observations had been made on a large quantity of potatoes stored in bulk, because a much greater amount of heat is evolved in a large than in a small quantity of potatoes.

The comparatively small weight loss from shrinkage in the 1925-26 studies may be explained as due in part at least to the use of more carefully selected seed stock. Weight losses are directly proportional to the quality of the tubers stored, their freedom from cuts and bruises as well as disease and, as previously stated, to temperature and humidity.

The temperature range for complete dormancy of bulk-stored potatoes is between 36° and 40° F. For the normal potato-storage period it is believed that a room temperature of 37° F. is sufficiently low to prevent germination and at the same time insure as low a transpiration and respiration loss as is desirable.

Comparative studies of the relative influence of different storage temperatures as conducted at the Virginia Truck Experiment Station, Arlington Experiment Farm, and Aroostook Farm did not reveal any marked differences in yields from the Irish Cobbler variety.

Lower yields were obtained at the Arlington farm from Green Mountain seed stored at 32° than at 36° or 40° F., while at Aroostook Farm there was no appreciable difference.

A fairly good increase in yield was obtained at the Arlington farm in 1921 from seed removed from storage and held for 12 days in a room temperature of approximately 70° F. as compared with the yield from similar stock planted direct from storage.

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