SOME PRACTICAL STORAGE INVESTIGATIONS WITH TABLE BEETS FOR SEED PRODUCTION PURPOSES

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Ernest Wilbur Scott

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SOME PRACTICAL STORAGE INVESTIGATIONS WITH TABLE BEETS FOR SEED PRODUCTION PURPOSES

Thesis

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by

Ernest Wilbur Scott

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V. R. Gardner

THESIS

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INTRODUCTION

In 1941, there were 2,182 acres, principally on the west coast, devoted to the production of 806,564 pounds of garden beet seed. Due to war time restrictions on the importation of European seed and to the poor crop in 1941, the 1942 crop has been increased to 4,442 acres with an estimated production of 2,911,600 pounds of seed.

For many years, some of the seed companies in the Northeast have been growing their own beet seed. This enables them to maintain lines which are carefully selected from a greater number of roots than would be practicable if they grew them only for stock seed purposes and had the main crop grown elsewhere. It also enables them to see that these lines are properly isolated and kept free from crossings with inferior lines.

The war has changed the United States from a seed importing nation to a seed exporting nation. Whereas we formerly obtained beet seed from Europe, we may now expect to ship seed to them. With this greater demand for beet seed, it would be poor policy to raise all our seed in one section of the country where adverse weather conditions might greatly reduce the seed crop. Since the transportation system of the country is overtaxed, it is even more important that an effort be made to keep up and perhaps increase the supply of garden beet seed grown in the East.

In the production of beet seed inthe East, it is customary to grow the mother beets one year, store them in outdoor pits or root cellars during the winter, and plant them out for flowering and seed production the following spring. During the storage period, many roots are lost from overheating, freezing, and to some extent, shriveling. It is the general opinion that storage conditions exert an important influence on seed production.

REVIEW OF LITERATURE

Data on actual experiments on the storage of garden beets for seed production are very limited.

Gaskill and Brewbaker stored sugar beets for seed for 125 days at 35.9° F. and 96.5% relative humidity with good results. The mean outside temperature for the storage period was 26.8° F. (4)

Wright, in storing beets for table use, recommended a temperature of 32° F. at a relative humidity of 95-98%. Beets may be expected to store satisfactorily under these conditions for one to three months. The freezing temperature of beets was given as 26.9° F., while 45° F. was the highest temperature at which beets could be safely stored. (5)

Chroboczek, in growing beet seed in a greenhouse, reported that freezing injury to the beet resulted in delayed seed stalk development. In a limited histological study, he found that seed stalk primordia grew abnormally at high temperatures. (2)

Vincent and Longley, in the Palouse section of Idaho, recommended storing garden beets for seed one half to one and one half inches in diameter. They recommended outdoor pits four to six feet wide, one to one and a half feet below the soil level, two feet above the soil level, and as long as necessary. A heavy covering of straw and up to 30 inches of soil were advised as protection against freezing. Bottomless boxes, 12 to 18 inches square, set at intervals along the top of the pit, were suggested for ventilation. To prevent shriveling, they suggested alternating layers of soil with the beets. (6)

Cox and Starr advised a pit very similar in shape to the one recommended by Vincent and Longley. A six inch sand covering topped with a layer of strawy litter was thought best for covering. Sifting sand between the beets was advised. The storing of mother beets in cellar bins, similar to those used for storing potatoes, was thought to be inferior to the outdoor pit. No actual experimentation was mentioned or discussed. (3)

Incomplete field records kept ty the Joseph Harris Company show that spoilage (no mention of type) has occurred in pits with and without soil.

Burrows, a grower for the Joseph Harris Company, reports good results for a period of six years with beets stored above soil level without soil about the roots. (1)

OBJECTIVES

The prime object of this investigation is to determine the maximum, minimum, and optimum storage temperatures at which garden beets may be stored for seed production purposes. It is hoped that this object may be attained by comparing the percent of beets suitable for planting and the seed yields from beets stored as follows:

1. In a commercial cold storage room,
2. In a root cellar,
3. In outdoor pits having varying amounts of covering,
4. In outdoor pits having varying amounts of ventilation,
5. In outdoor pits with and without soil about and over the beets.

A secondary object is to determine whether satisfactory yields of seed may be grown from small beets stored in cold storage.

MATERIALS AND METHODS

Using mother beets grown for seed production purposes in Monroe County, New York, several types of pit storage, root cellar storage, and commercial cold storage were tried during the fall and winter of 1941 and 1942.

All mother beets used were field run, fall grown beets. They were planted about July 1, 1941, and grown in much the same manner as beets for the cannery. They ranged in size from one to six inches; most of them were two and one quarter to three inches in diameter. They were pulled and topped, i.e., all leaves cut off about two inches from the crown, by hand and placed in storage on October 28, November 1, and November 2. There had been no heavy frosts up to that time. The variety used was Detroit Dark Red.

Six bushels were stored in a commercial cold storage room in which the temperature was kept at 33°-35° F. and the relative humidity at 85-90%. All were stored in open slat crates whose sides had been lined with light weight cardboard. Four bushels had sand around and over the beets, one bushel had peat moss around and over the beets, and one bushel had nothing over and around the beets. These beets remained undisturbed in storage until the day before planting on April 1.

Seven bushels of mother beets were stored in a root cellar commonly used for the storing of Brussels sprouts. The root cellar dimensions were as follows: 40 feet long, 20 feet wide, approximately 15 feet high at the center, and 8 feet high at the eaves. It was all above soil level, but soil had been thrown up against its side walls as high as the eaves. The root cellar was ventilated by a set of double doors on the north end, a set of double windows on the south end, four side wall ventilators, and one roof ventilator. The beets were stored on its sandy floor in a pile approximately the same size and shape as the outdoor pit dexcribed below. (See figures 1 and 2.) Soil was thrown between and over the beets. The only covering used was one inch of soil. Temperatures in the root cellar were taken with a Taylor maximum-minimum thermometer. Temperatures within the pile of beets were taken with thermocouples and a galvanometer. (Details described below.) The placement of the thermocouples in the beet pile was approximately the same as the placement of those in the check outdoor pit. (See figure 1.)

To serve as a check for other outdoor pit experiments and for use in comparing pit storage with root cellar and cold storage, seven bushels of mother beets were pitted in the manner usually employed by the Joseph Harris Company of Coldwater, New York, i.e., the beets were pitted with soil around them and covered with eight to ten inches of straw applied November 21, six inches of soil applied November 25, and eight to ten inches of horse manure applied December 17. Figures 1 and 2 give the pit dimensions as well as the placement of the thermocouples in the

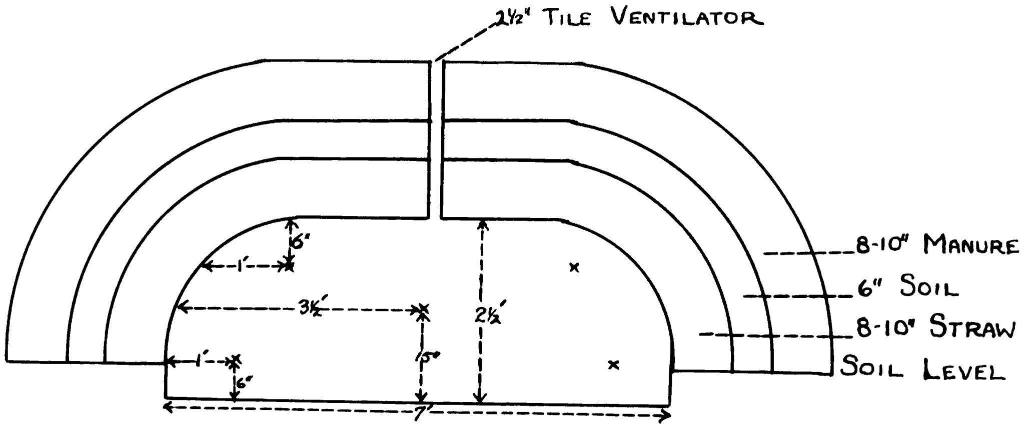


FIGURE 1. Long. crossection of the check pit. X denotes placement of the thermocouples.

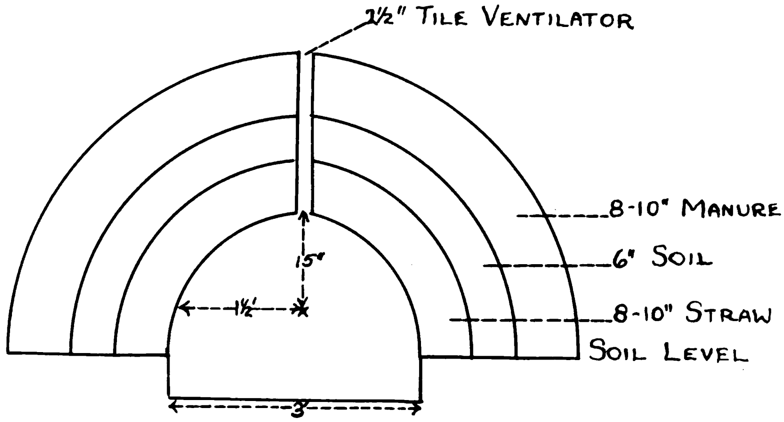


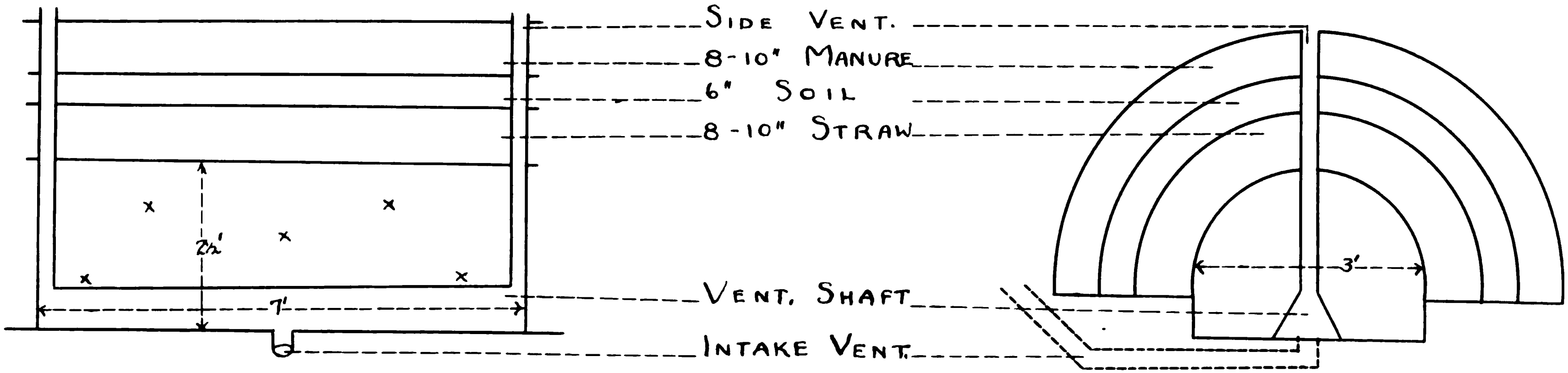
FIGURE 2. Transverse crossection of the check pit. X denotes placement of the center thermocouple.

check pit.

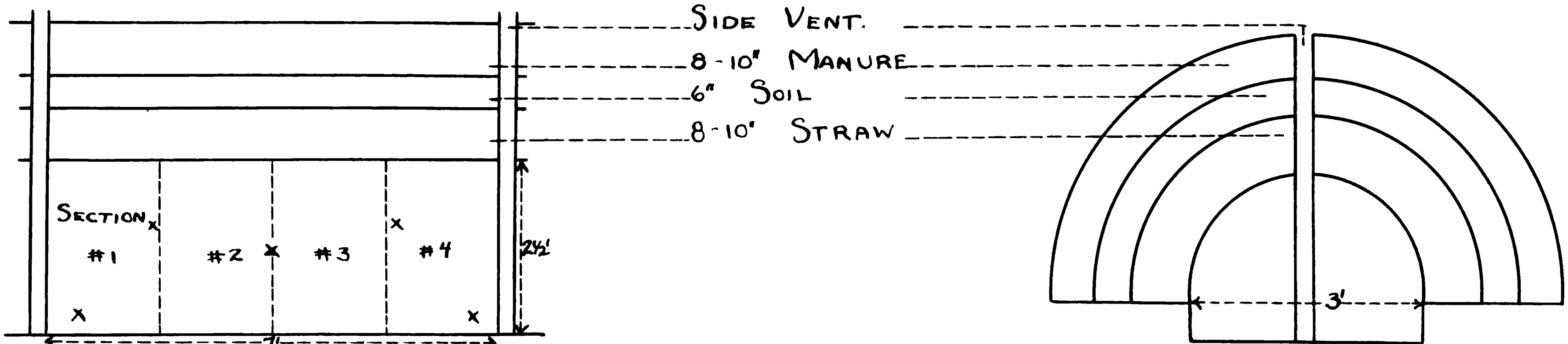
Two outdoor pits in addition to the check pit were constructed with the object of determining the approximate amount of covering necessary. As far as possible, these pits were constructed the same as the check. The size and shape and the placement of the thermocouples were the same as is shown in figures 1 and 2 above. One pit had one half the covering of the check, i.e., four to five inches of straw, four inches of soil, and four inches of manure, while the other had one fourth the covering of the check, i.e., two inches of straw, two inches of soil, and two inches of manure. The covering materials were applied the same times as those of the check. No ventilator was put in the pit with only one fourth the covering of the check.

One outdoor pit in addition to the check was constructed with the object of determining the need for soil about the beets. This pit was constructed and covered the same as the check in all details except that no soil was placed with the beets.

Two outdoor pits in addition to the check were constructed with the object of determining the amount of ventilation needed in pits. These pits were constructed and covered very much like the check except for the ventilators. Both pits had ventilators set seven feet apart and running down both sides. In addition to the side ventilators, one pit had a ventilator shaft at the bottom of the pit. This ventilator shaft was not only connected with the side ventilators, but with an intake ventilator running under the pit to the outside. All ventilators were made of two and one half inch drain tiles. The ventilator shaft was made of chicken wire stretched over a rectangular framework of "one by twos". Figures 3 and 4 give dimensions and shape of the latter pit, and figures 5 and 6 give size and shape of the other pit. It may be noted that these pits were separated from the check by about thirty feet of pit



FIGURES 3 and 4. Long. and transverse crossection of pit ventilated in sides and bottom. X denotes placement of thermocouples.



FIGURES 5 and 6. Long. and transverse crossection of pit ventilated in sides only. X denotes placement of thermocouples. (Explanation of sections is on page 37.)

and that they had no ends, i.e., beets were pitted continuously on both ends. They were separated from each other by about ten feet of pit.

In addition to the above pits, temperatures were taken and observations made on the regular pits of the Joseph Harris Company. The pits were much longer than the experimental pits, but otherwise were the same dimensions. Thermocouples were placed at about 20 foot intervals in the pits, and at ground level. Covering and construction were the same as the check pit.

For taking soil temperatures, a thermocouple was placed six inches in the soil adjacent to the check pit.

All pits had five thermocouples which were placed as is shown in figures 1 and 2. The thermocouples were made by connecting a four foot number 18 copper wire to a four foot number 20 advance wire. The junction was enclosed in a test tube and the wires insulated with rubber tubing. All pit temperatures were taken on a Weston Galvanometer (model 440) previously calibrated to read in degrees Fahrenheit above or below 32° F., i.e., the temperature of melting ice in which the check thermocouple was inserted. The check thermocouple was placed in a test tube filled with fine copper filings. This test tube was then inserted in a thermos bottle in which ice was melting. Frequent checks on the temperature of the check thermocouple were made with a regular laboratory thermometer. Figure 8 shows the set up of the galvanometer and check thermocouple connected to a pit thermocouple. Below is a picture of the galvanometer in position for temperature taking on one of the pits.

FIGURE 7. Galvanometer on pit.

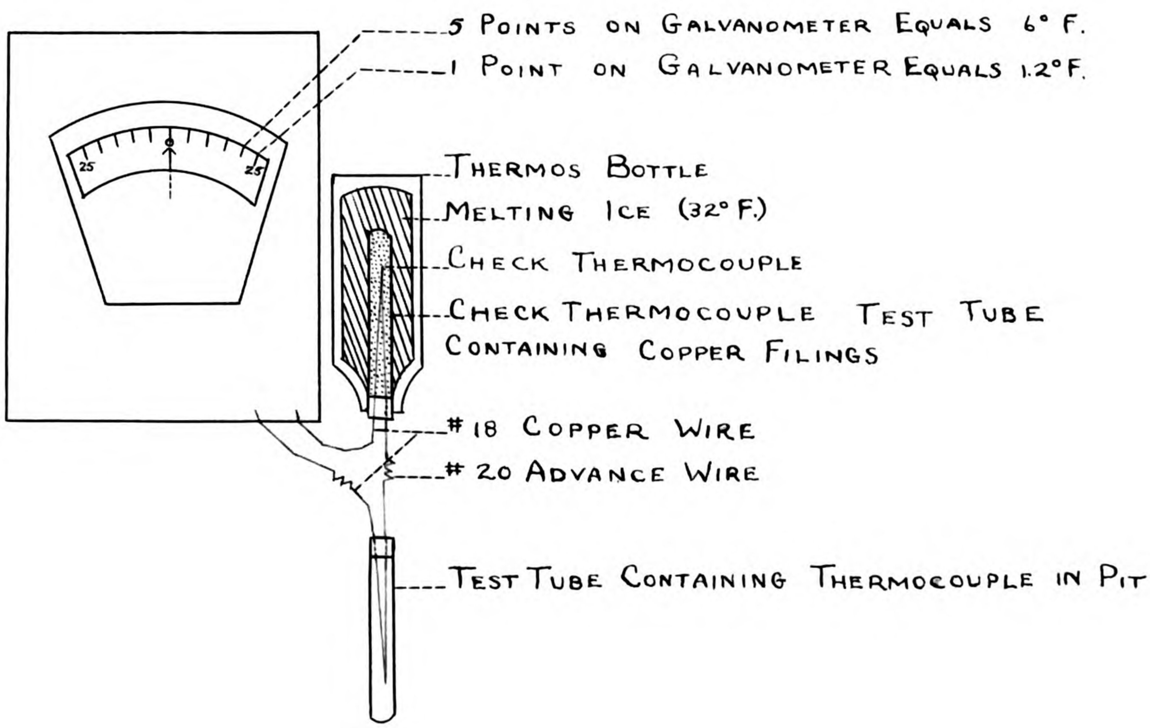


FIGURE 8. Diagram of galvanometer and thermocouples.

Temperatures in the pits were taken daily from pitting until December 21, thereafter they were taken weekly until April 5, when they were taken twice each week until planting.

The mother beets were removed from the pits in layers as is shown in figure 9. As the beets from each zone were removed, they were sorted into those suitable and those unsuitable for planting. These were then counted or measured as the case required, and the percentage of beets suitable for planting, calculated. All small and extra large beets were sorted out of those suitable for planting.

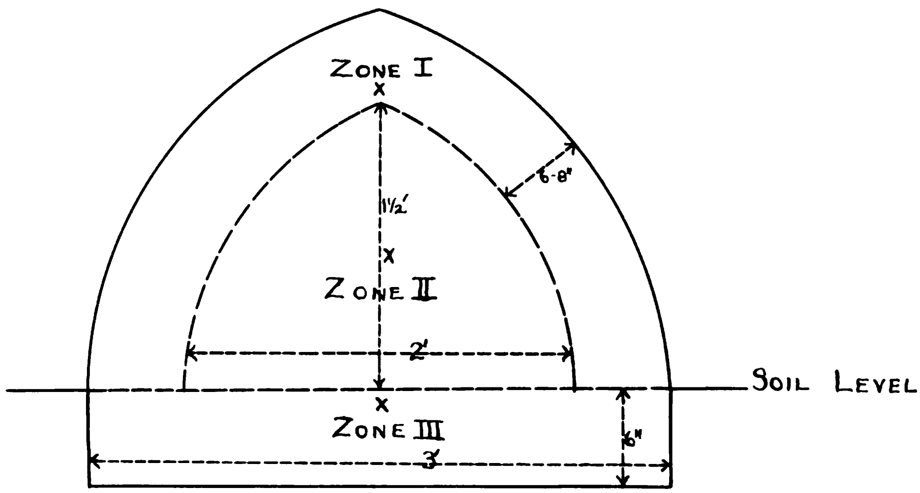


FIGURE 9. Crossection of pit showing zones used in removing beets from the pits. X denotes placement of thermocouples.

A two and one half bushel sample taken proportionally from each zone from each pit (except the pit ventilated in the sides only) was planted in 650 foot rows, along with comparable samples of beets stored in the root cellar and in cold storage in sand. Shorter rows of beets which had been stored in cold storage in peat moss, in cold storage without any covering, and of small beets (size) sorted out of those stored in cold storage in sand were planted adjacent to the regular planting. The beets were planted two feet apart in three foot rows by a transplanter similar to those used in transplanting tomato or cabbage plants.

Notes were taken on the height of leaves or seed stalks three times, i.e., 17, 31, and 79 days after planting. Stand counts were taken four weeks after planting.

Seed was harvested from a total of 250 feet of each of the 650 feet rows. One half of the 250 feet was at the north end of the rows, while the other half was near the middle of the rows. All the seed was harvested from the 161 foot row planted from beets stored in cold storage in peat moss; the 69 foot row planted from beets stored in cold storage without any covering; and from the 135 foot row, planted from the small beets sorted from those stored in cold storage in sand. The seed stalks in each section were counted, cut, and allowed to dry on wire screens in the field. After about a week of drying, the seed was flailed by hand and the sticks and small and light seed removed on a small seed mill. All lots of seed were milled as nearly alike as possible. Germination tests of 100 seeds of both large and small seeds from each lot of seed were run and the viable seeds counted. If the small seed germinated 50% or more after remilling, it was added to the large seed. The germination tests were run on standard blotting paper in a regular seed germinator at 80° F. Counts were made at three and ten days after tests were placed in the germinator.

PRESENTATION OF TEMPERATURE DATA

The mean and normal outdoor temperatures for the months in which beets were stored are given in table 1.

TABLE 1. Mean and normal outdoor temperatures for the storage period. (U.S. Weather Bureau records for Rochester, N.Y.)

	Nov.	Dec.	Jan.	Feb.	March	April
Mean 1941-1942	43.0	31.8	24.4	20.4	35.6	50.2
Normal	38.7	29.4	24.6	24.7	31.8	44.9

The total precipitation, the normal precipitation, the total snowfall, and the normal snowfall for the months in which beets were stored, are given in table 2.

TABLE 2. Total and normal precipitation and snowfall for the storage period.

	Nov.	Dec.	Jan.	Feb.	March	April
Total Ppt.	1.05	2.24	1.28	4.51	5.24	2.6
Normal Ppt.	2.54	2.27	2.89	2.69	2.76	2.35
Total Snowfall	0.2	5.9	5.0	31.5	18.4	5.3
Normal Snowfall	6.4	16.9	19.5	16.6	12.9	3.9

The average weekly temperatures and the maximum and minimum temperatures are shown in figure 10.

The lowest temperature observed during the storage period was -10° F. on January 8. During this cold spell, which lasted from January 5 to January 12, the temperature went below zero four times. Two less severe and

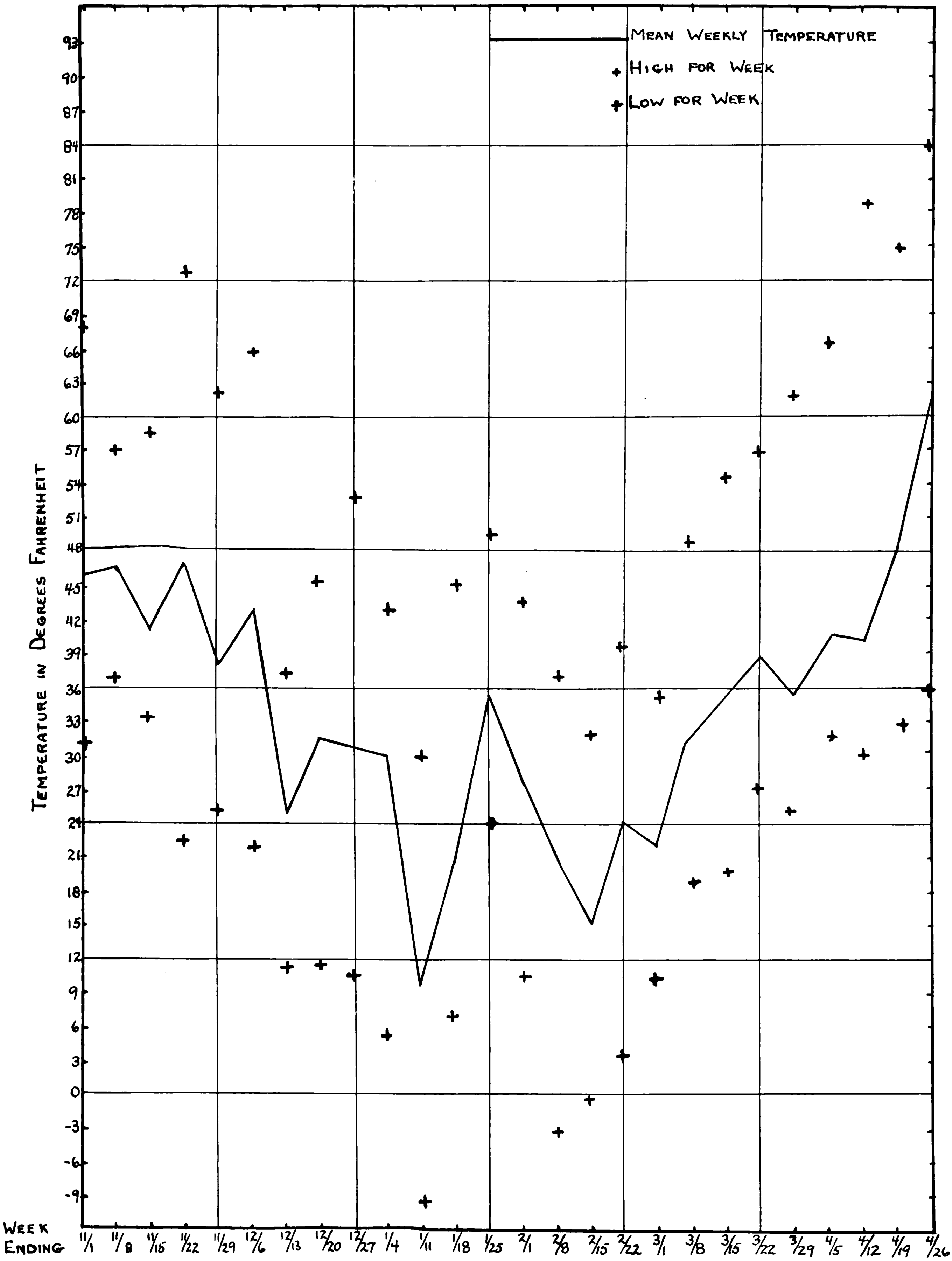


Figure 10: Mean Weekly Temperatures Observed at U.S. Weather Bureau Station, Rochester, N.Y.

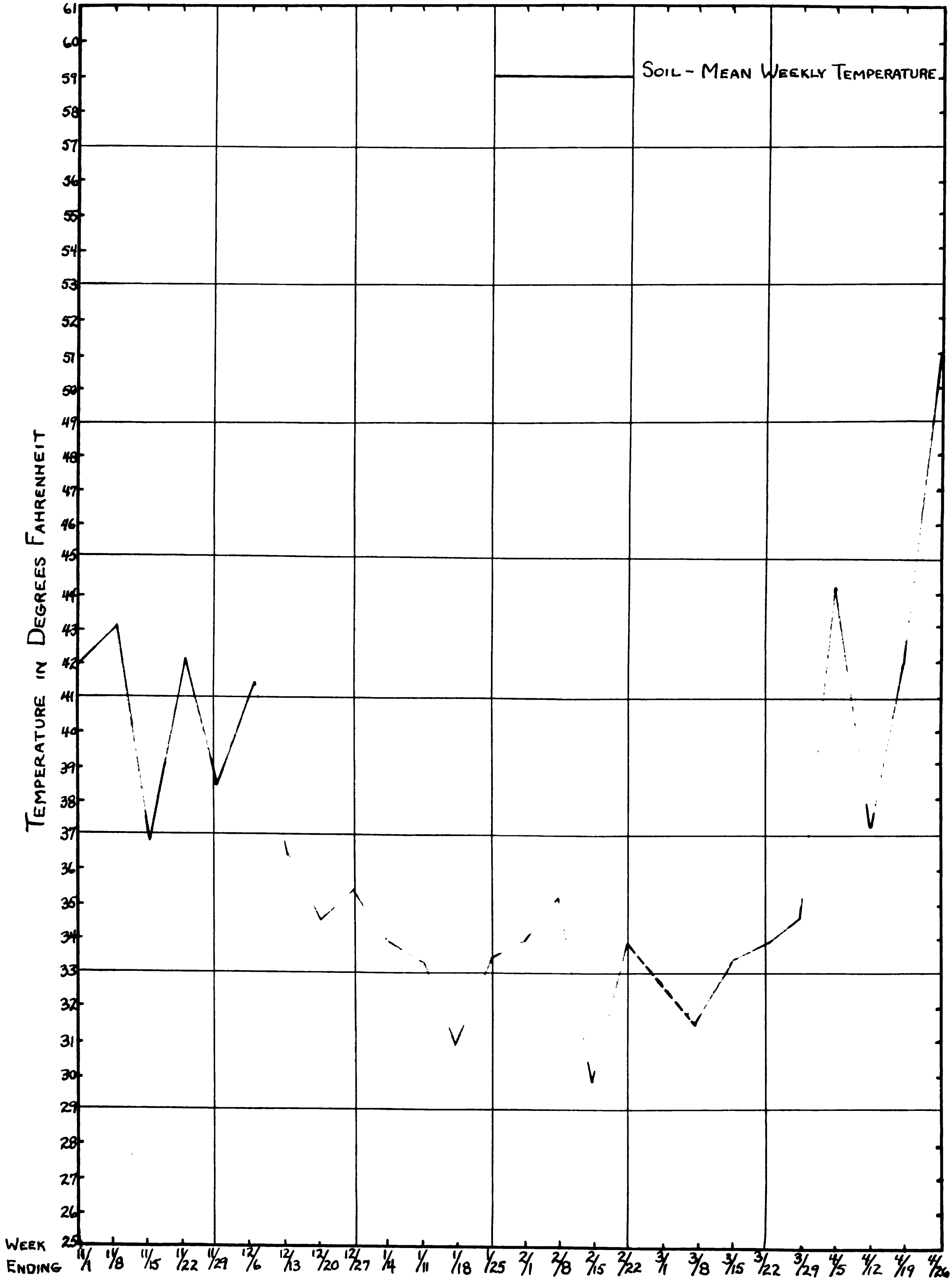


Figure 11: Average Weekly Soil Temperatures.

shorter cold spells occurred in February with temperatures going to 4° F. on February 3, and to 1° F. on February ninth and tenth.

The highest temperature observed during the storage period was 84° F. on April 26. The high during the fall months was 73° F. on November 19th. An abnormally warm period occurred during the first week in December, during which the temperature reached a high of 66° F. on December fourth.

The average weekly soil temperatures are shown in figure 11.

In comparing temperatures of mother beets held in cold storage, root cellar, and pit storage, the cold storage beets with a constant temperature of 33°-35° F. averaged much lower than the root cellar with an average of 38.79° F., or the check pit with an average of 40.50° F. The temperatures of mother beets stored in the root cellar and the check pit are shown in figure 12. Except for two weeks in November and four weeks in March, the root cellar temperatures were below those observed in the check pit. Faulty management of the root cellar was probably responsible for the high temperatures there during November. Following covering of the check pit with straw and soil on November 21 and 25, it may be noted that temperatures of the root cellar beets dropped, while those of the check pit rose. Thereafter, until March 15, the root cellar pit temperatures remained one to five degrees below those of the check pit. Temperatures in the root cellar pit

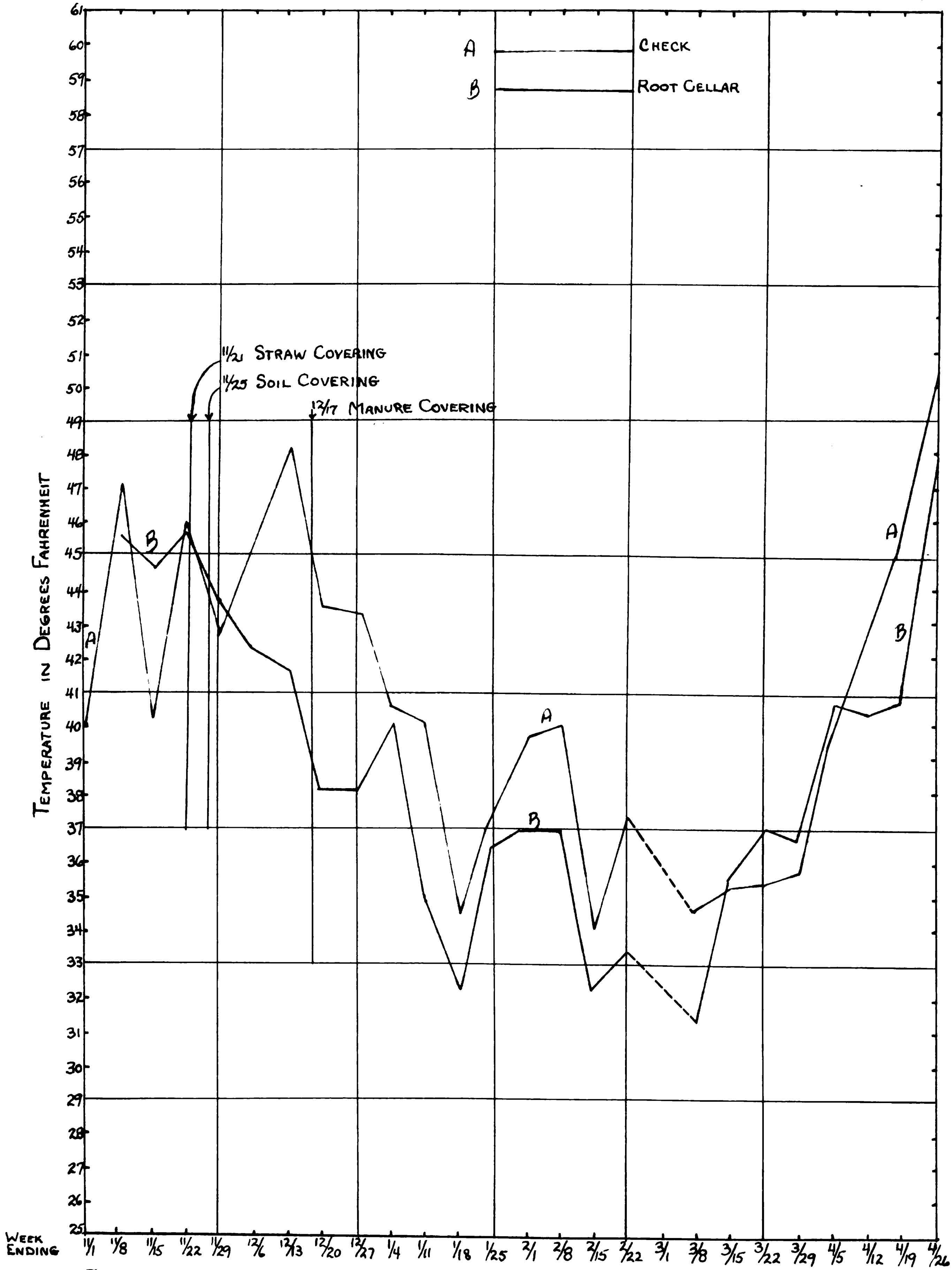


Figure 12: Average Weekly Temperatures Observed in the Root Cellar and the Check Pit.

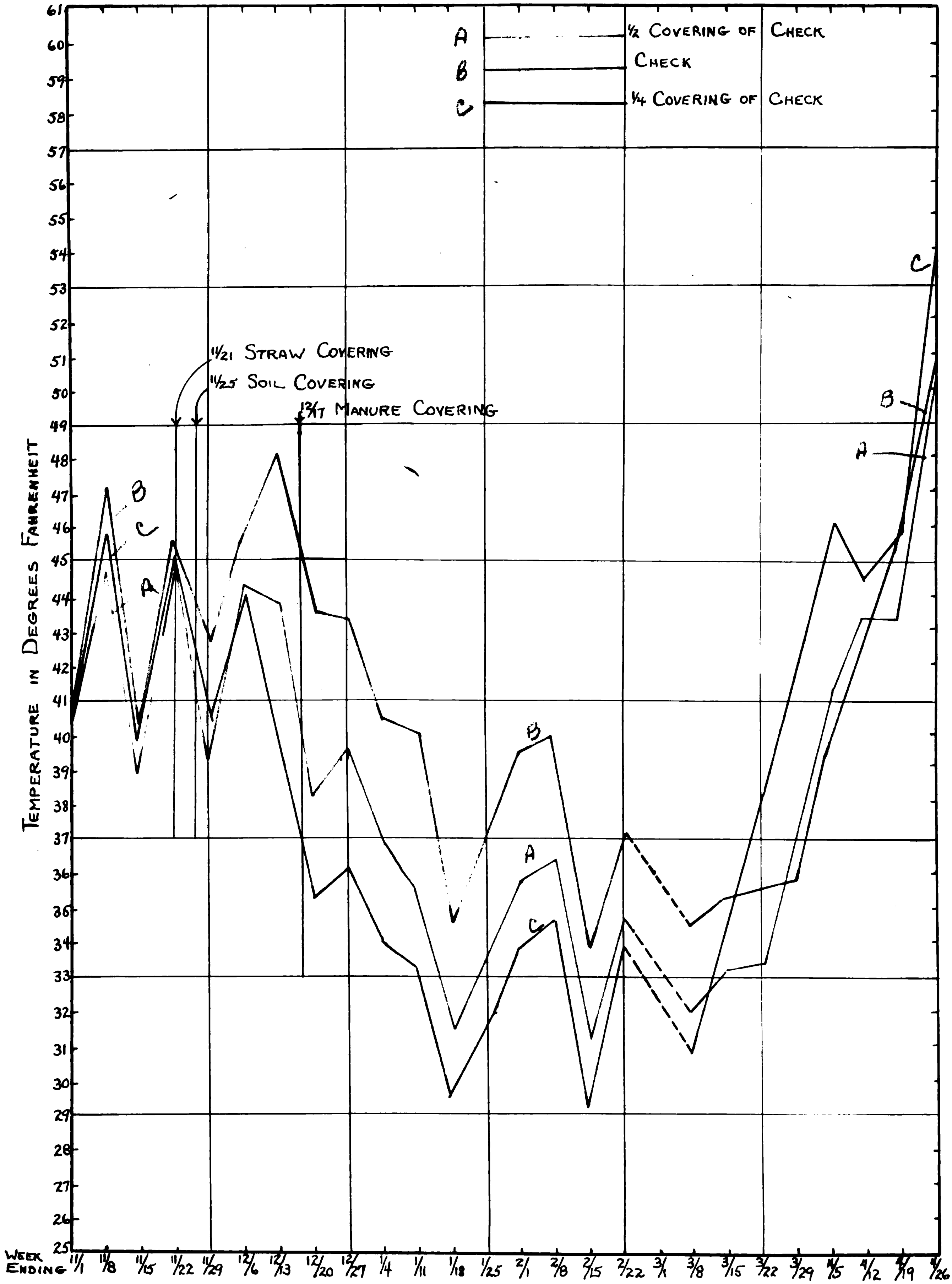


Figure 13: Average Weekly Temperatures Observed in the Check and Covering Pits.

started to rise earlier, but less rapidly than any of the outdoor pits. The check in the rise in temperatures in the root cellar pit which occurred from April 5 to April 19, might give evidence that temperatures in a root cellar may be controlled more easily than those in pit storage.

The average temperatures for the storage period of the check pit, the pit with one half the covering of the check, and the pit with one quarter the covering of the check were 40.5° F., 38.2° F., and 38.3° F., respectively. The average weekly temperatures of these pits are shown in figure 13. The temperatures in these pits were very much the same until November 21 and 25, when straw and soil covering were added. The differences in temperatures observed following the straw and soil covering became still greater when manure was added on December 18. It may be noticed (see figure 13) that the check pit temperatures continued to rise on December 6, while those of the other two pits showed a decrease, similar to that but not as great, as the one observed in the root cellar during this period. (See figure 12) Until March 8, the pit temperatures fluctuated quite uniformly together. During this period, the pit with one quarter the covering of the check always had the lowest temperatures. On January 18, a low of 26° F. was observed and on February 15, a low of 27° F. was observed in the top section of this pit. It may be assumed that temperatures of 26°-27° F.

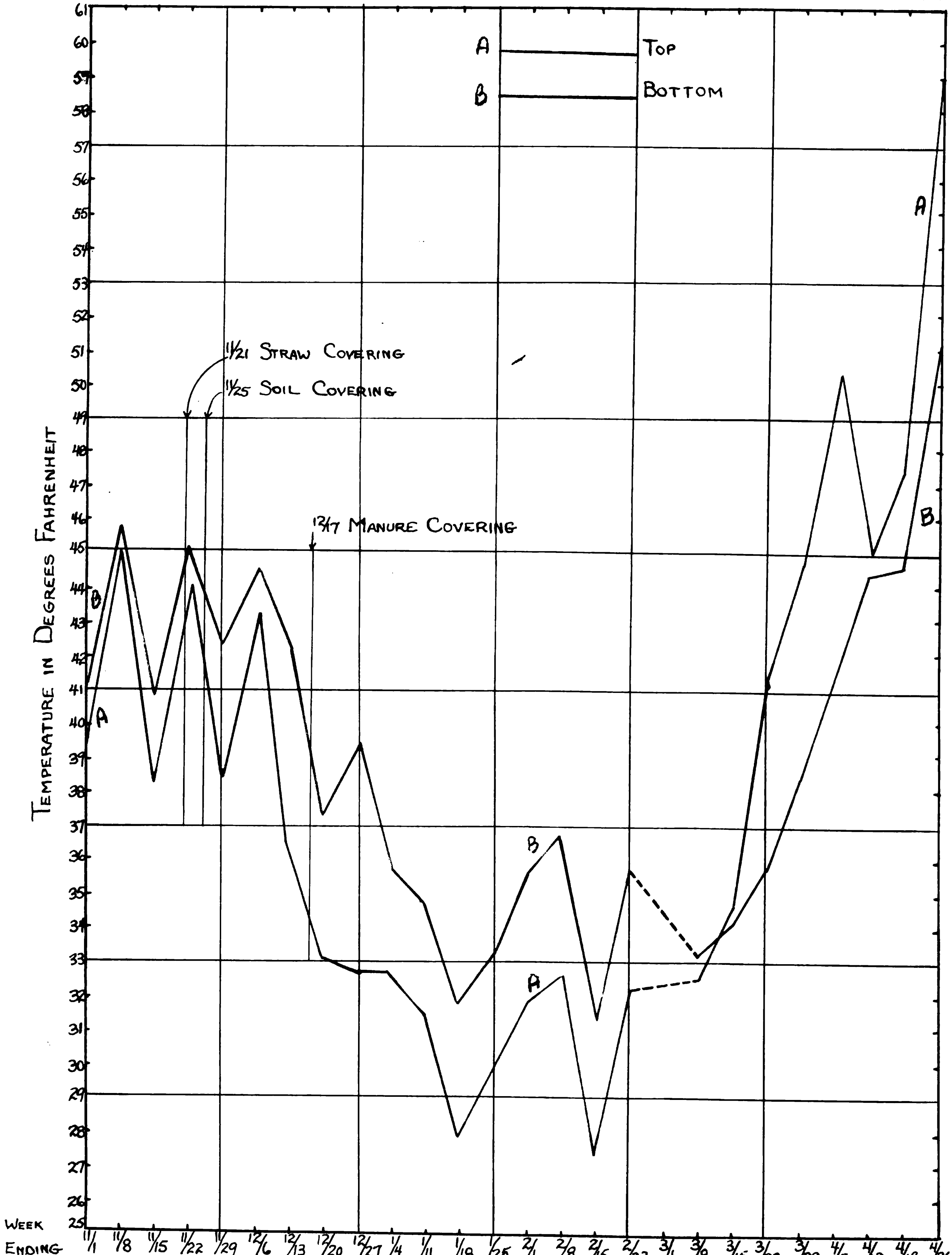


Figure 14: Average Weekly Temperatures Observed in Top and Bottom of Pit with One Quarter the Covering of the Check.

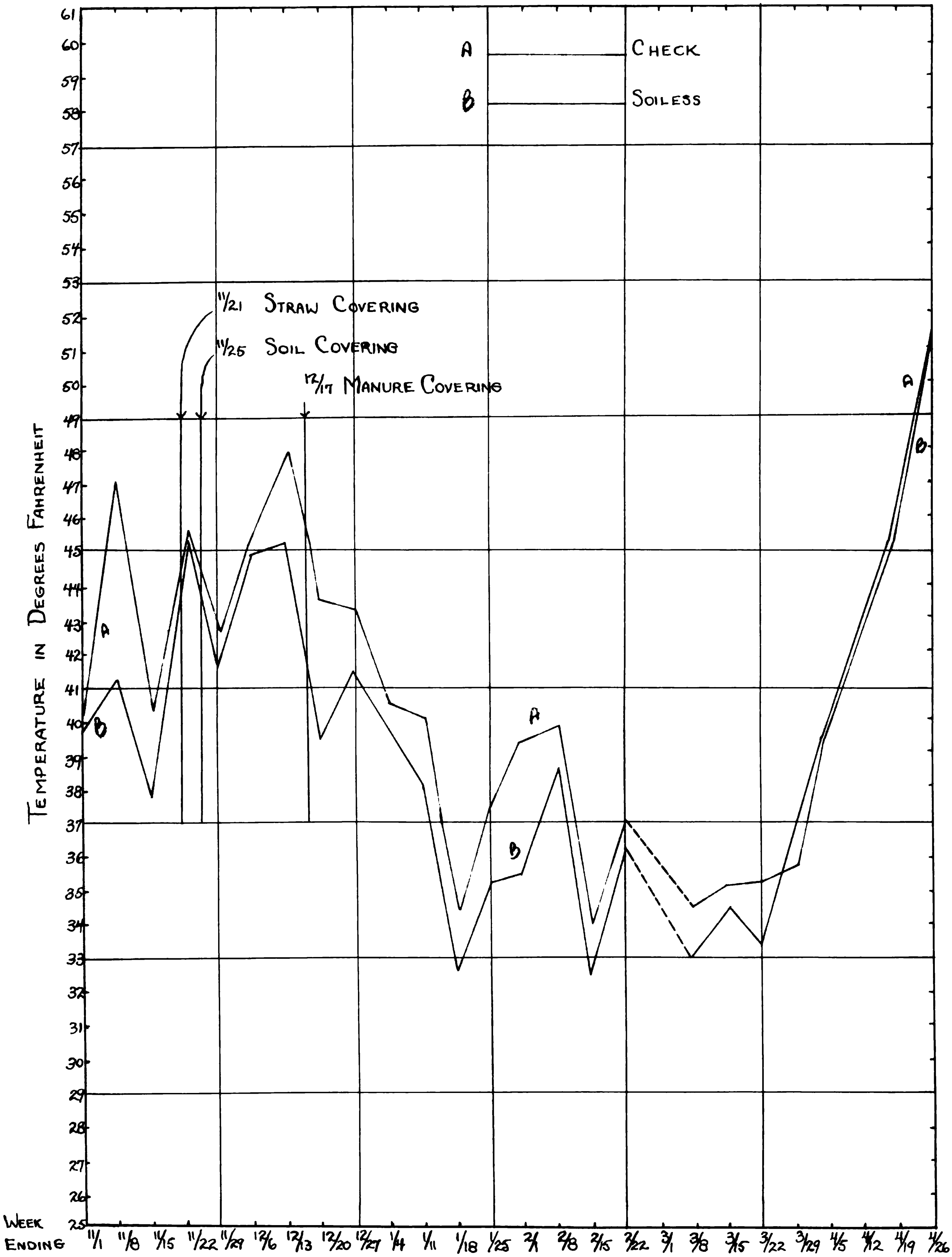


Figure 15: Average Weekly Temperatures Observed in Soiless and Check Pits.

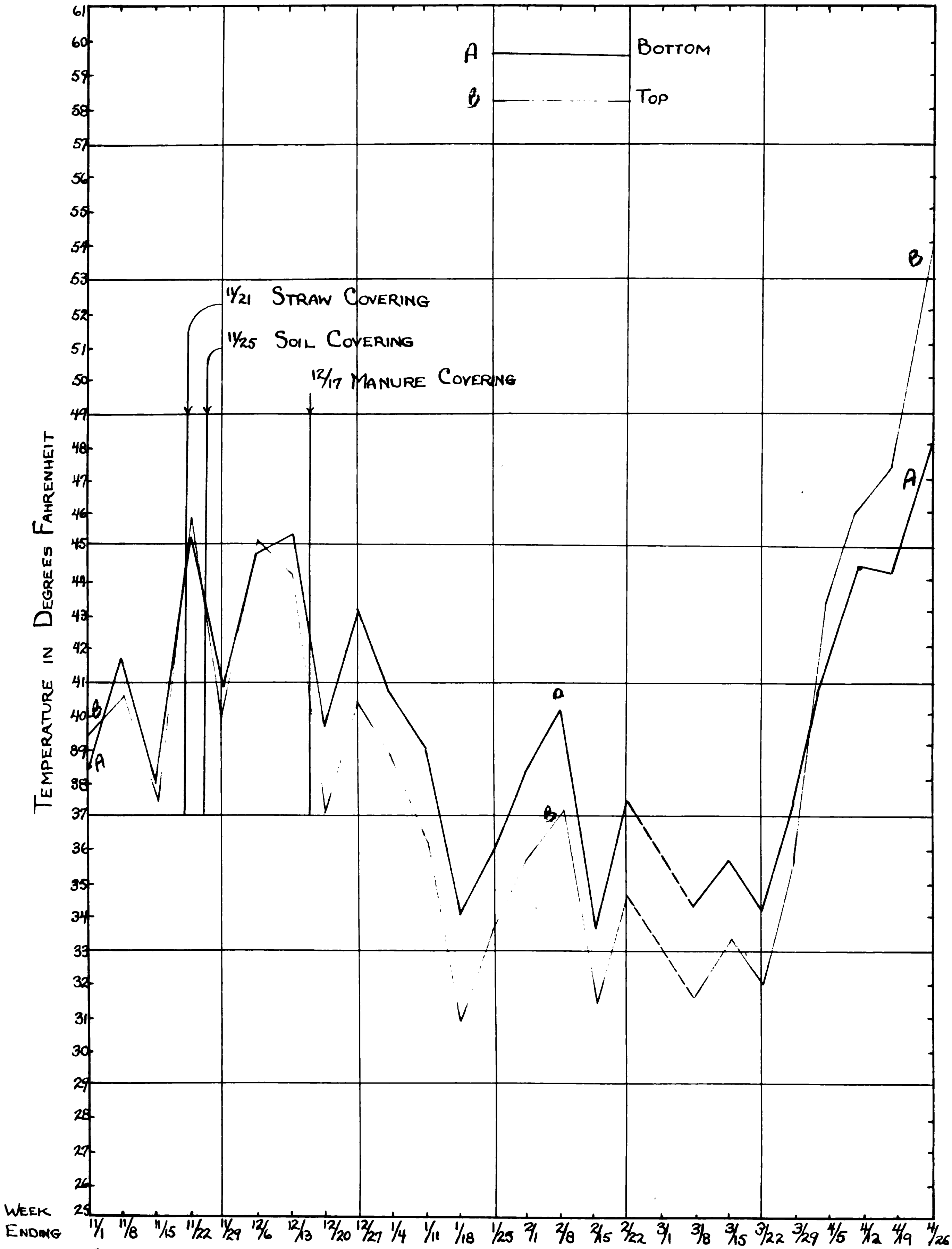


Figure 16: Average Weekly Temperatures Observed in Top and Bottom of Soiless Pit.

lasted for two weeks or more in this pit. The lowest temperatures observed in the pit with half the covering of the check were 29° F. on January 19 and February 15. These temperatures were observed in the top section of the pit. No freezing temperatures were observed in the check pit. During the week of March 8-15, the temperatures in the pit with one quarter the covering of the check began to rise more rapidly than in either of the other pits. This rise, which was more rapid than than the outside temperature during this period, continued until April 5, when a temperature of 50° F. was observed in the top of the pit. The drop in temperatures in the top of this pit (see figure 14) from April 5 to April 12, was also out of line with the outside temperatures. The rise in temperatures of the other two pits during this period was much the same except that the check pit rose more slowly at first and more rapidly during the latter part of the storage period.

The average weekly temperatures observed in the check pit and the soiless pit are shown in figure 15, while those observed in the top and bottom sections of the soiless pit are shown in figure 16. It may be noted that the temperatures observed in the soiless pit were below those of the check pit. The lowest temperature observed in the soiless pit was 30.4° F. in the top section of the pit. It is doubtful whether this temperature lasted over three or four days as the temperatures of the week

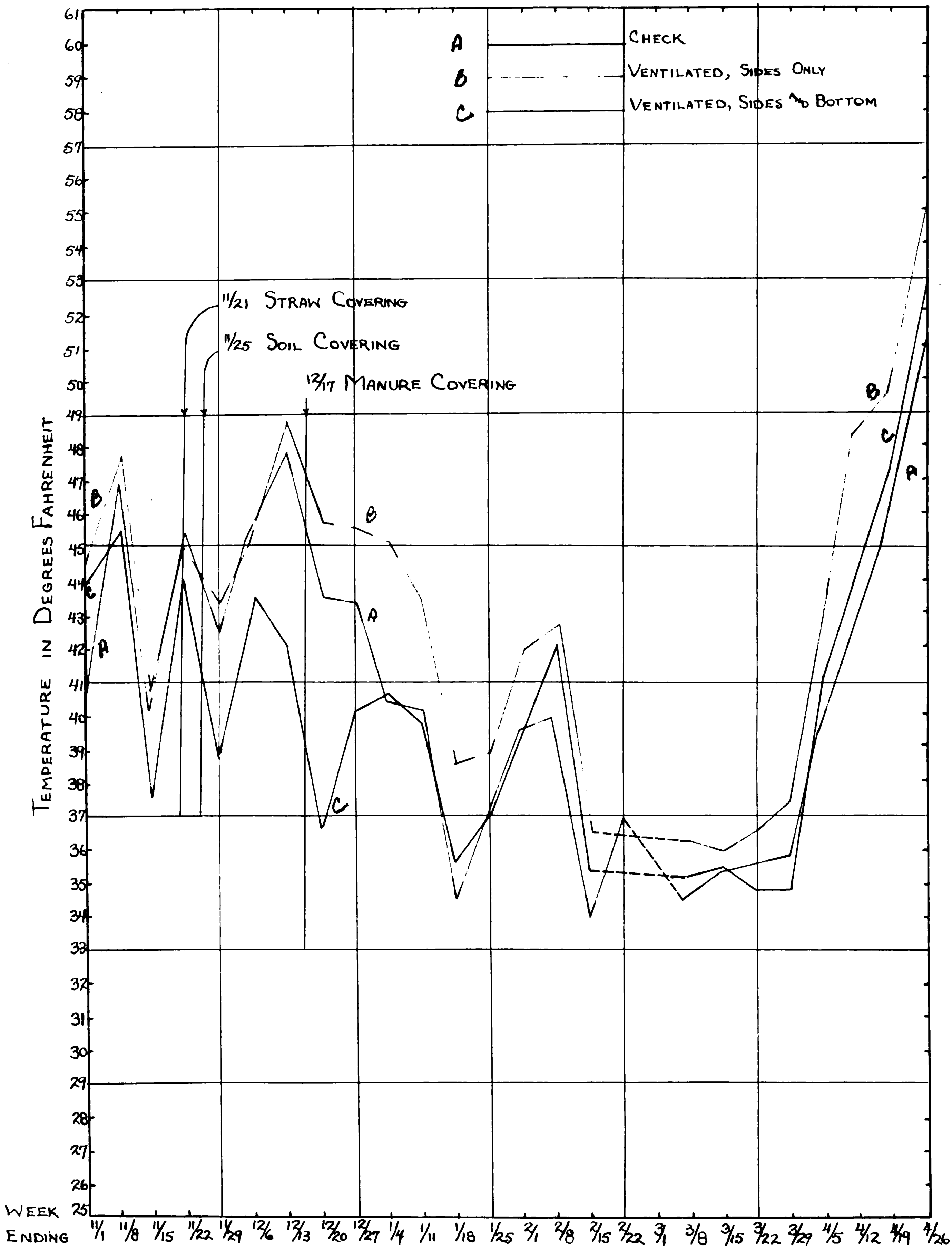


Figure 17: Average Weekly Temperatures Observed in Ventilated and Check Pits.

before and following were well above this low temperature. The temperatures observed in the soiless pit during April were nearly the same as those observed in the check. The average temperature for the storage period in the soiless pit was 39.08° F.

The average weekly temperatures observed in the check pit and the two ventilated pits are shown in figure 17. It may be noted that during November and December, when the ventilators in the ventilated pits were opened during cold weather and closed during warm weather, that the temperatures in the pit ventilated on both sides and bottom were somewhat below those of the check pit. The temperatures in the pit ventilated on the sides alone were about the same as those in the check during this period. It may be noted also that the temperatures in the pit ventilated on both sides and bottom showed a decrease, similar to the decrease mentioned above in the two covering pits and the root cellar, on December 6, while the check pit and the pit ventilated on the sides only showed an increase. Following plugging of the ventilators for the winter on December 17, the temperatures in the pit ventilated on both sides and bottom rose to temperatures approximating those of the check, while the temperatures of the pit ventilated on the sides rose above those of the check pit. The temperature in the pit ventilated on the sides only began to rise earlier and more rapidly than either the check or the other ventilated

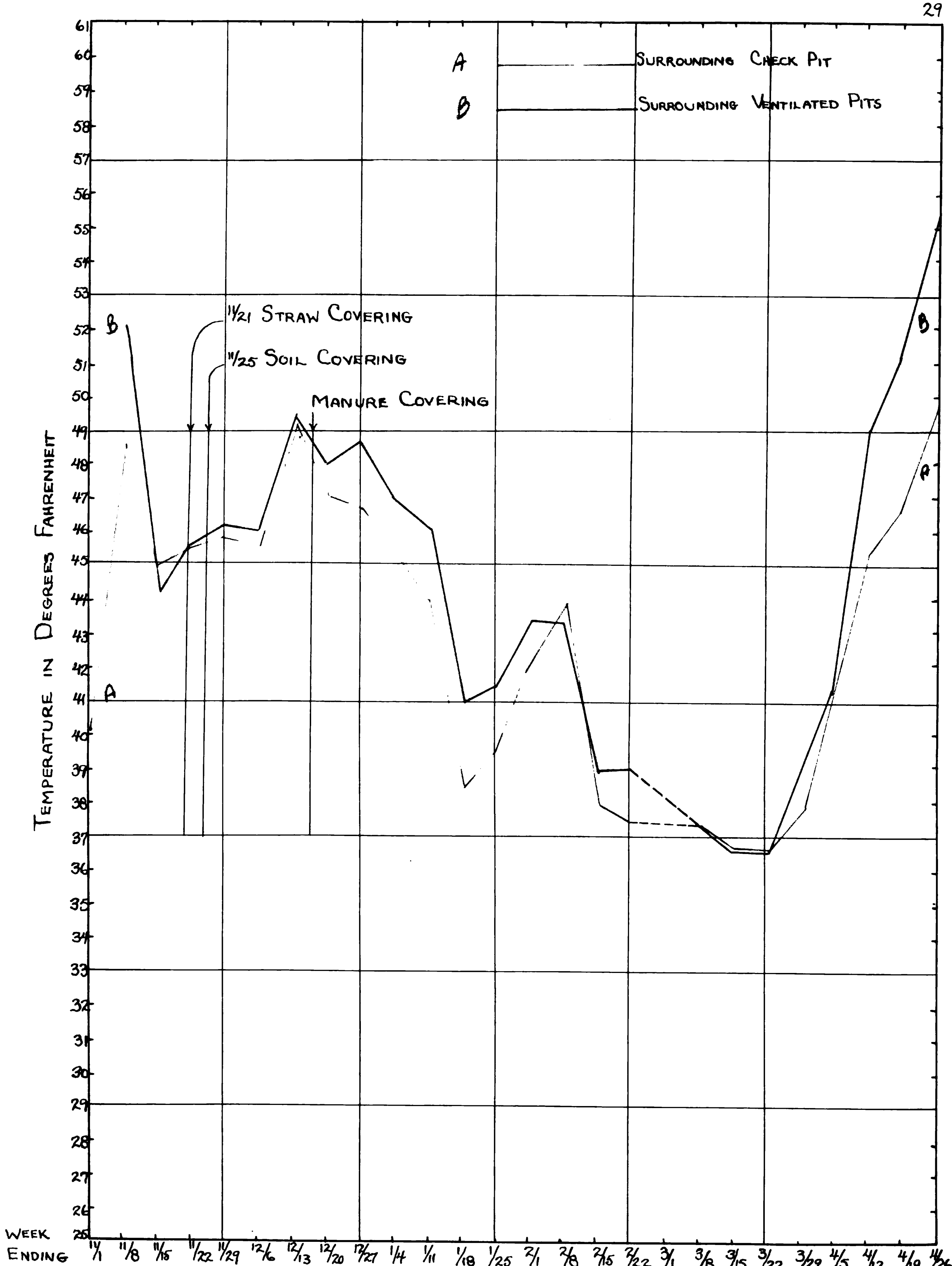


Figure 18: Average Weekly Temperatures Observed in Pits Surrounding Check Pit and Ventilated Pits.

pit. For the last two and one half weeks of the storage period, this pit had temperatures above 45° F. The average temperature for the storage period was 40.8° F. in the pit ventilated in both sides and bottom, 42.6° F. in the pit ventilated in sides alone, and 40.5° F. in the check. The two west thermocouples in the pit with ventilation in sides only averaged 1.2° F. higher than the two east thermocouples.

Figure 18 shows a comparison of temperatures of beets pitted immediately surrounding the two ventilated pits and temperatures of beets pitted immediately surrounding the check pit. It may be noted that the pits surrounding the ventilated pits had higher temperatures throughout most of the storage period and that they showed an earlier and more rapid rise in temperatures than did the ventilated pits.

PRESENTATION OF STORAGE DATA

All beets stored in cold storage, the root cellar, and the check pit, were suitable for planting.

Mother beets stored in cold storage in sand were entirely dormant. They had no root hairs or sprout growth, other than that which they had when stored. Except for a few on top of the crates which were not completely covered by the sand, they were all firm fleshed. Figure 19 shows three typical beets stored in sand in cold storage.

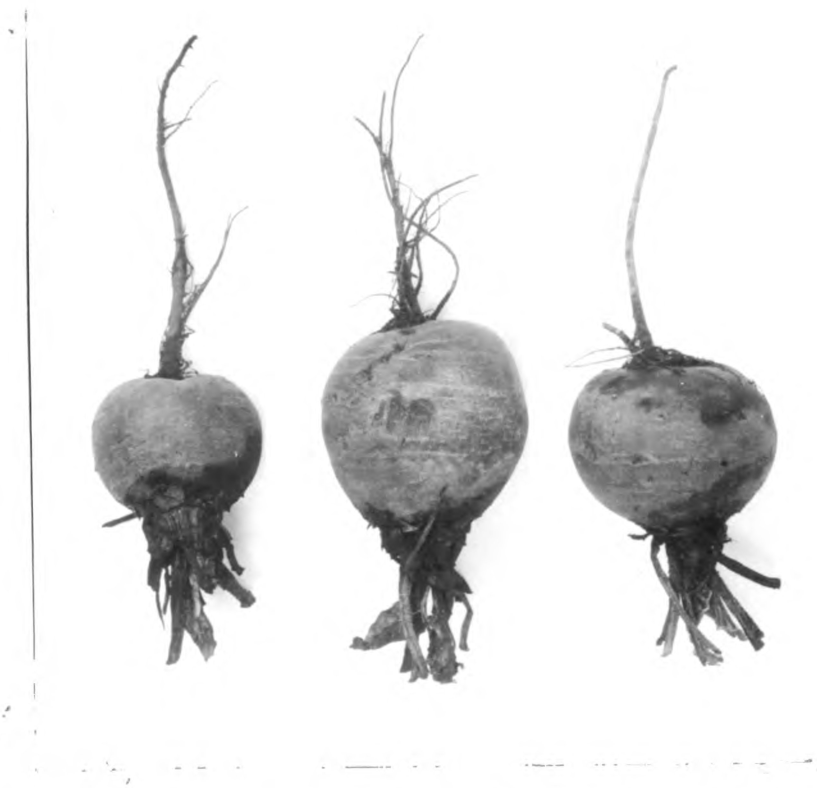


FIGURE 19. Three typical beets after removal from cold storage.

Beets stored in cold storage in peat moss were very much the same as those stored in sand. The beets stored without sand or peat moss about them were slightly shriveled but otherwise the same as those stored in peat moss and sand.

Beets stored in the root cellar had longer sprouts and more root hairs than beets stored under any other condition. They were all firm. Figure 20 shows three typical beets stored in the root cellar.

FIGURE 20. Three typical beets after removal from the root cellar.

Beets stored in the check pit had an abundance of root hairs and fairly long sprout growth. The beets from all sections of the pit were nearly alike. There was no indication of frost, overheating, or drying out injury in this pit.

The percentage of beets suitable for planting from the pits with different amounts of covering are given in table 3.

TABLE 3. The percentage of beets suitable for planting from two covering pits and the check.

	Zone 1*	Zone 2*	Zone 3*
Check	100 %	100%	100%
½ Covering of Check	93.1%	100%	100%
¼ Covering of Check	50%	82.3%	100%

* See figure 9 for explanation of zones

The pit with one half the covering of the check showed six and nine tenths per cent of the beets with freezing injury in zone one. This frost injury was confined to the crown of the beet. The beets in zones two and three were much the same as those of the check pit.

The beets stored in the pit with one quarter the covering of the check showed considerable frost damage in both top zones, i.e., zones one and two. The frost damage in zone one was very severe, i.e., the entire beet was rotted at the time of removal, while the frost damage in zone two was less severe and consisted mainly of rotted crowns. Fourteen per cent of the beets in zone two and eighteen per cent of the beets in zone three and a slight rotting of the tap root, but were considered suitable for planting.

All beets stored in the pit without soil about them were classed as suitable for planting in spite of the fact that nearly all showed some rotting of the tap root. On some beets, just the tip of the tap root was affected, while in others, the rotting extended into the beet proper as much as one half an inch. The most severe injury occurred in the top of the pit (zone one) where 46 per cent of the beets showed severe injury. The center of the pit was less affected with 33 per cent showing severe injury, and the bottom of the pit (zone three) was least affected, with 23 per cent showing severe injury. Figure 21 shows three severely injured beets. The dry brown rotting

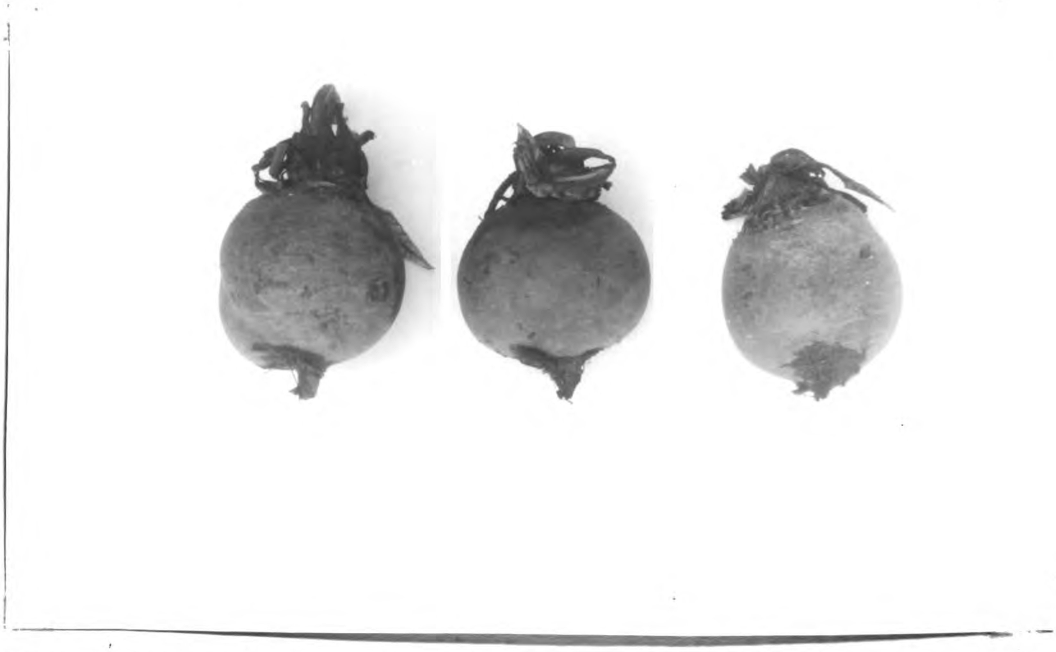


FIGURE 21. Three severely injured beets from the soiless pit.

seemed to start at the tip of the tap root and worked towards the beet proper. In many cases, the tap root seemed normal, but a slight jar or pull would break it off. The sprout growth on all beets in this pit was much shorter than in any of the other pits. The only good vigorous root hair growth observed was in beets which were in contact with the soil at the bottom of the pit.

The percentage of beets suitable for planting from the two ventilated pits and the check are given in table 4.

TABLE 4. Percentage of beets suitable for planting from the ventilated pits and the check pit.

	Zone 1	Zone 2	Zone 3
Check	100%	100%	100%
Vent. Sides and Bottom	100%	100%	100%
Vent. Sides Only	83.1%	94.5%	69.5%

The beets stored in the pit ventilated on both sides and bottom were very much the same as those stored in the check pit. Sprouts were longer and root hairs more numerous around the ventilators. Figure 22 is a picture of three typical beets from this pit.

The beets stored in the pit ventilated on the sides only showed injury which was probably due to overheating. The most common injury was to the sprout and crown and the area around the crown. In severe cases, the whole sprout was jet black and brittle, while the crown and the top half

FIGURE 22. Three typical beets stored in the pit ventilated on both sides and bottom.

of the beet was covered with a watersoaked rotting which scuffed off when rubbed. In less severe cases, only the tips of the sprouts and the old leaf petioles were black and circular water soaked areas appeared on the shoulder of the beets. In crossection, these water soaked areas were black and confined to the surface of the beet. Overheating damage was evident to some extent in all parts of the pit, but it was most severe in zone three and the lower parts of zone one. Figure 23 shows how the covering material slid to the base of the pit, covering the areas where heat injury occurred with an excessive amount of covering material. It was also noticed that more severe

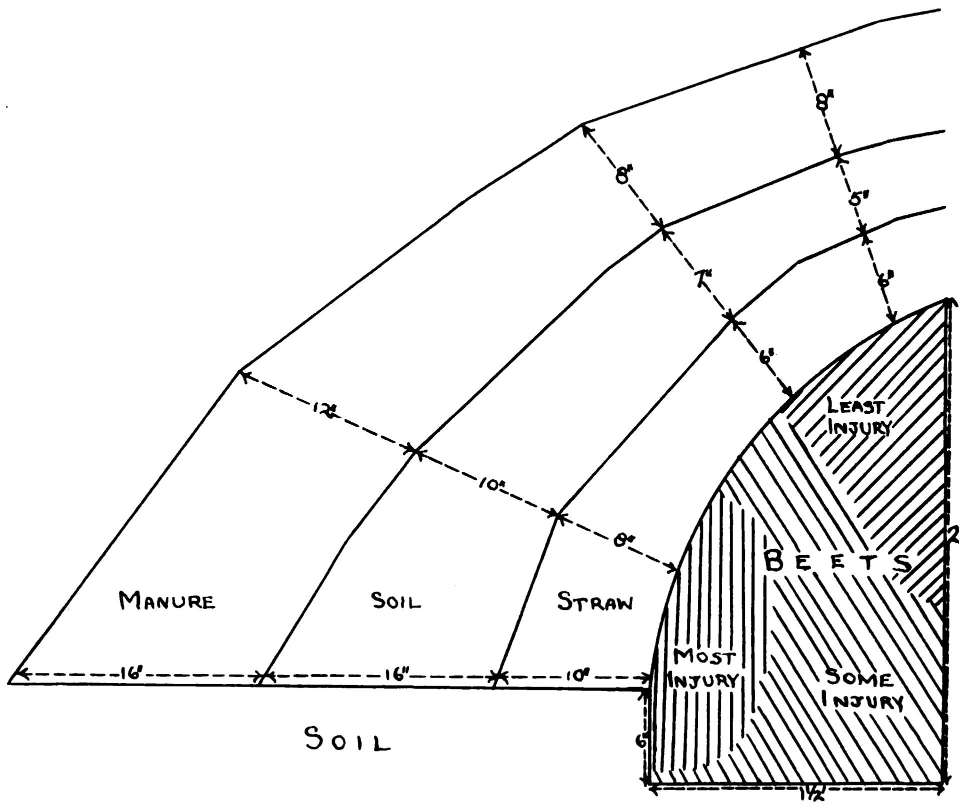


FIGURE 23. Relation of cover at end of storage period to heat injury.

injury occurred near the west ventilator than around the east ventilator, so counts were taken in four sections (see figure 5) as well as in zones. Starting with section one, i.e., the section adjacent to the west ventilator, the percentages of beets suitable for planting were 97.5%, 83.0%, 65.0%, and 72.0% respectively. Section one contained the east thermocouples and section four, the west thermocouples.

The beets in the pits on either side and between these two ventilated pits had up to 50 per cent severe injury from overheating.

PRESENTATION OF SEED PRODUCTION DATA

The spring and summer of 1942 were ideal for beet seed production. Warm weather during the early spring made it possible to plant the beets early. Rainfall was abundant and well distributed throughout the growing period.

Table 5 gives the per cent stand and the average length of leaves or seed stalks at 15, 31, and 79 days after planting. The seed stalks were just beginning to appear

TABLE 5. The per cent stand 15 days after planting, the average height in inches 15, 31, and 79 days after planting, and the per cent rosette seed stalks. Data on 550 feet of row.

TYPES OF STORAGE	% STAND	AVERAGE HEIGHT IN IN. 15	31	79 days	% ROSETTE SEED STALKS
Cold Storage, Sand	96.8	3.4	9.4	41.2	5
Cold Storage, Peat Moss	---*	--*	9.0	41.3	4
Cold Storage, No Covering	---*	--*	8.4	44.5	0
Cold Storage, Small	---*	2.1	7.1	38.7	6
Root Cellar	91.2	2.8	7.9	40.5	11
Pit-½ Covering of Check	82.4	2.3	7.0	38.7	29
Pit-¼ Covering of Check	75.1	1.8	5.7	42.0	28
Pit-Check	83.7	2.3	7.6	37.6	29
Pit-Soiless	76.1	2.2	7.5	40.0	25
Pit-Vent. Sides and Bottom	86.7	2.6	8.3	40.9	24

* Data not collected

at the first measurement, just above the leaves at the second measurement, and were in full bloom and at their maximum height for the third measurement. It may be noted that the beets stored in cold storage and the root cellar made much the better stand and early growth, but that as the seed stalks matured, the beets stored in pits caught up to and in one case, i.e., the pit with one fourth the covering of the check, exceeded the height attained by them. It was noted, during the growing period, that the seed stalks produced by beets stored in cold storage were more uniform in height than the seed stalks produced from beets from the other storage treatments.

It was noticed that many of the beets stored in the outdoor pits produced seed stalks with no main stem, but instead, a rosette of several lesser stems. These stems, unlike the more common main stems which grew from the single crown of the beet, grew from the shoulder of the beet. The percentage of beets producing seed stalks with the rosette growth habit is given in table 6 above.

The yield in pounds per acre from the two plots of each storage treatment are given in table 6, along with the germination of each lot of seed and the calculated yield in pounds per acre and pounds per plant at 80% germination. Since there were quite large differences in the germination of the various lots of seed, it was thought advisable to convert the yields to pounds of seed per acre on the basis of 80% germination.

TABLE 6. Yield in pounds per acre, germination, and yield in pounds per acre and pounds per plant on the basis of 80% germination.

TYPES OF STORAGE	REPLI-CATE	GERMI-NATION %	YIELD LBS. PER ACRE	CALCULATED YIELD LBS. PER ACRE AT 80% GERM.	MEAN	CALCULATED YIELD PER PLANT IN LBS. 80% GERM.	MEAN
Cold Storage,	A	75	1379.38	1310.41	1339.5	.194	.191
Sand	B	69	1539.16	1369.85		.187	
Root Cellar	A	82	1375.77	1403.28	1254.5	.224	.197
	B	79	1118.04	1106.86		.170	
Pit-Vent. Sides	A	72	862.12	793.15	827.5	.129	.139
and Bottom	B	75	936.54	842.89		.148	
Pit-$\frac{1}{2}$ Covering	A	77	822.19	797.53	771.5	.156	.145
of Check	B	77	784.08	746.56		.134	
Pit-Check	A	81	696.96	703.92	707.5	.132	.133
	B	80	711.48	711.48		.133	
Pit-Soiless	A	64	726.00	624.36	643.0	.138	.131
	B	73	711.48	661.68		.124	
Pit-$\frac{1}{4}$ Covering	A	75	649.77	617.25	561.0	.133	.137
of Check	B	80	504.62	504.62		.140	
Cold Storage-Small		74	1330.31	1250.50		.175	
Cold Storage-Peat Moss		73	1092.00	1015.56		.175	
Cold Storage-No Covering		86	1121.25	1188.52		---*	

* Data Missing

TABLE 7. The number of seed stalks per acre at harvest. (100% stand = 7260 seed stalks per acre)

	COLD STORAGE	ROOT CELLAR	PITS				
			VENT.	½ COVER. OF CHECK	CHECK	SOILESS	¼ COVER. OF CHECK
Replicate A	6795	6272	6156	5111	5343	4530	4647
Replicate B	7260	6506	5691	5576	5343	5343	3600
Average	7028	6389	5924	5344	5343	4937	4124

TABLE 8. Analysis of variances and covariance of the stand and yield data.

	Stands = x			-xy	Yields = y		Errors of Estimate		
Source of Variation	D. F.	Sum of Squares	Mean Square	Sum of Products	Sum of Squares	Mean Square	Sum of Squares	D. F.	Mean Square
Total	13	12,319,060		3,296,762	1,164,666		282,452	12	
Between Treatment Means	6	11,031,110	1,838,517	3,263,159	1,109,489	184,915			
Error	7	1,287,950	183,993	33,603	55,177	7,882	54,300	6	9,050
Treatment	6						228,152	6	38,025

b from the error line is 0.02609; b from treatment plus error is 0.2676
▪ 9,050 = 95.13

The stand at harvest in seed stalks per acre, for the various treatments is given in table 7.

Table 8 contains the analysis of variance and covariance of the numbers of beets per acre and the pounds of seeds produced per acre. On examining the F value pertaining to stands or numbers of beets per acre, namely;

$$F_x = \frac{1,838,517}{183,993} = 9.99,$$

it is seen that there are significant differences between the stand averages. This shows that the treatments caused significant differences in the numbers of beets to survive, grow, and produce seeds.

On examining the F value pertaining to yields per acre, namely;

$$F_y = \frac{184,915}{7,882} = 23.5,$$

it is seen that there are highly significant differences between yield means. One of the reasons why the yield means are significant is because of the differences in stands and these differences are no doubt brought about by differences in treatments.

The slopes of the regression lines pertaining to error and treatment plus error are respectively as follows:

$$b = .02609$$

$$b = .\ 2676$$

These slopes differ significantly from each other. The first slope indicates that there is not a great deal of dependence between stands and yields; the latter indicates that there is some dependence of yield on stands. The last three columns in table 8 contain the analysis after adjusting for stand. The F value pertaining to yields adjusted for stands, namely;

$$F = \frac{38,025}{9,050} = 4.23,$$

lacks .05 of being significant at the 5% level. This indicates that perhaps some of the mean yields after adjusting for stands are significantly different from others, since it is a border line case. The averages of the yields before and after adjusting for stand are given in table 10.

TABLE 10. Yields of seeds per acre before and after adjusting for stands.

	COLD STORAGE	ROOT CELLAR	PITS				
			VENT.	½ COV. CHECK	CHECK	SOILLESS	¼ COV. CHECK
Av. before adj. for stands	1340	1255	818	773	708	643	561
Av. after adj. for stands	1302	1234	809	779	714	660	584

Differences in means to be significant = 232 at 5% level and 353 at the 1% level.

Clearly the adjustment yield means for the cold storage and the root cellar treatments are significantly larger than the other treatment yield means. There is no significant difference between the adjusted yield means of the cold storage and the root cellar treatments and no significant differences between the adjusted yield means of the other treatments.

Table 11 contains the analysis of variance of the yields per plant. (See table 6) The value of F from this table, namely;

$$F = \frac{.009,586}{.002,028} = 5.22,$$

TABLE 11. Analysis of variance of the yields per plant.

SOURCE OF VARIATION	D.F.	SUM OF SQUARES	MEAN SQUARE
Total	13	.011,614	
Between Treatment Means	6	.009,586	.001,514*
Error	7	.002,028	.000,290

* Significant at the 5% level. = .017

suggests that there are significant differences between treatment means. On testing for significance, it is found that the difference between yield per plant averages to be significant is .042 pounds at the 5% level and .059 pounds at the 1% level. The means of the cold storage and the root cellar treatments are significantly larger than the means of the other treatments. There are no significant differences between the other treatment averages.

DISCUSSION AND CONCLUSIONS

In attempting to draw conclusions from the above data, it must be borne in mind that they are the results of but one years's work and thus cannot be taken as wholly conclusive.

The use of thermocouples and a galvanometer for taking temperatures in pits proved to be a very laborious and time consuming operation. It proved very difficult to take temperatures in mid-winter when snow, ice, and cold weather made handling the thermocouple wires a painful and at times an impossible task. From the above data, the author thinks it can be safely assumed that in all but the scantily covered pits, the critical months of storage were November, December, March, and April. During these months, temperature readings can easily be taken with the galvanometer and thermocouples. The use of thermocouples and a galvanometer in taking temperatures in the root cellar proved to be much easier and could be used to good advantage in taking temperatures there in either bins or pits.

The fact that some beet crowns froze at approximately 30° F. in the pit with one half the covering of the check seems to indicate that any temperature below freezing for any length of time is dangerous in storing mother beets for seed purposes. Since no tissue damage from freezing was observed in this pit at this temperature, it may be assumed that tissue damage from freezing takes place at temperatures between 27° F., i.e., the lowest temperature observed in the pit with one fourth the covering of the check which showed severe freezing injury, and 30° F. These deductions are in line with the 26.9° F. freezing point for beets given by Wright. (5) Since a beet is of no value for seed purposes if its crown is frozen, we may say that storage temperatures as low as 30° F. should be avoided.

To determine from the above data the t emperatures which will cause heat injury is difficult if not impossible. Since temperature readings were not taken daily during the last three weeks of the storage, and due to the fact that some of the beets remained in the regular pits as long as ten days after the last temperature observations were made on April 26, it is difficult to state the exact number of days during which the pits were above a set temperature, i.e., any arbitrarily picked temperature at which heat injury was thought likely to appear. However, through interpelation of the temperature data an hand, the following table was constructed, (table 12) giving the approximate number of days during which the beets surrounding each of the thermocouples were above 45°, 48°, and 50° F.

In selecting the thermocouples for table 12, only borderline cases, i.e., those which showed no heat injury but which had relatively high temperatures, and those which showed varying degrees of heat injury were used. It may be gathered from this table that beets may be stored without serious decay for approximately 68 days at temperatures of

TABLE 12. The relationship of heat injury to the number of days in which temperatures of beets surrounding selected thermocouples were above 45°, 48°, and 50° F.

PIT	THERMOCOUPLE	% HEAT INJURY	APP. NO. DAYS ABOVE 45°	48°	50° F.
Vent., Sides and Bottom	Center	0	32	26	20
Regular*	20' E. of Center	0	68	32	16
Regular*	3' from W. End	1%	50	9	0
Vent., Sides Only	East, Soil Level	10%	56	32	20
Regular*	Center	15%	69	49	21
Vent., Sides Only	West, Soil Level	28%	68	49	29
Regular*	20' from W. End	27.7%	81	54	33

* Regular pit refers to pits constructed by Joseph Harris Company for storing their main crop of beets.

45° F. or over, providing not more than 32 of these days have temperatures of 48° F. or over, or more than 20 of these days have temperatures of 50° F. or over. No other thermocouple with surrounding beets showing heat injury failed to have less than 68 days at 45° F. or over, or less than 32 days at 48° F. or over, or less than 20 days at 50° F. or over. No other thermocouple which showed no heat injury had more than 68 days at 45° F. or over, or more than 32 days at 48° F. or over, or more than 20 days at 50° F. or over.

The average temperatures for the storage period, the

TABLE 13. The average storage temperature, the time, in per cent of the storage period, in which the temperatures of the various treatments were below 32° F., between 32-40° F., and above 40° F., and the mean seed yields per plant and per acre of the various treatments.

TYPES OF STORAGE	AV. STORAGE TEMPERATURE Degrees F.	PER CENT OF STORAGE PERIOD WITH TEMPERATURES Below 32°	32-40°	Over 40°	MEAN SEED YIELD (GER.80%) Pounds Per Plant	Pounds Per Acre
Cold Storage, Sand	33	0	100	0	.191	1339
Root Cellar	38.8	4	56	40	.197	1245
Pit-Vent. Sides and Bottom	40.8	0	54	46	.139	827
Pit-Check	40.5	0	46	54	.133	707
Pit-½ Covering of Check	38.3	12	54	34	.145	771
Pit-Soiless	39.1	0	46	54	.131	643
Pit-¼ Covering of Check	38.2	15	43	50	.137	561

Yield differences of .042 pounds per plant and 232 pounds per acre are significant.

per cent of the storage period during which the temperatures of the various storage treatments were below 32° F., between 32-40° F., and above 40° F., and the mean yields of the various storage treatments are given in table 13. It may be noted that the mean yields decreased as the average storage temperatures and the per cent of the storage period above 40° F. increased, if the temperatures of the pits with one quarter and one half the covering of the check and the soiless pit are not considered. Freezing temperatures were observed in these two covering pits for 15 and 12 per cent of the storage period respectively. These low temperatures not only lowered the average storage temperatures of these pits, but caused the obvious freezing injury discussed above. It would seem logical to assume that the low yield per plant, the poor stands, and the low yield per acre from beets stored in these pits, may have been due to unapparent injury due to freezing. This assumption is supported by the findings of Chroboczek, (2) who reported that freezing injury to beets growing in a greenhouse delayed seed stalk development. Low yields from beets stored in the soiless pit can be attributed to the serious tap root rotting observed in that pit.

Since Wright (5) found that table beets gave off 35% and 300% more heat (which he assumed was due to respiration of hexose sugars) at 40° F. and 60° F. respectively than at 32° F., it seems logical to assume that the beets stored at the higher temperatures, i.e., those stored in the outdoor pits which showed no storage injury in this investigation, lost more sugars than those stored at the lower temperatures i.e., the cold storage and root cellar storage. This leads to the conclusion that greater sugar losses may be responsible for the poorer stands, the lower yields per plant, and the lower yields per acre obtained from the beets stored at the higher pit temperatures. Other storage conditions such as ventilation, moisture, etc., may have helped cause the low yields from the beets stored in the outdoor pits.

The cause of the rosette seed stalk growth is difficult to explain with the limited data obtained. It may be noticed in table 6 that there were a greater percentage of rosette seed stalks produced by beets stored in outdoor pits than were produced by beets stored in the root cellar or in cold storage. The higher storage temperatures observed in the outdoor pits may have been the cause. This reasoning is in line with the finding of Chroboczek. (2) In conducting an investigation to determine the cause of bolting in beets, he found that temperature had a marked influence on the formation and growth of seed stalk primordia. Further investigation would be necessary to determine whether this or other storage or field conditions caused this abnormal seed stalk growth. Although no yield data was obtained on individual rosette seed stalks, the lower yields per plant obtained from the outdoor pits would indicate that their yield per plant was less than that obtained from normal seed stalks.

In this investigation, it was possible to get the land fitted and the beets planted at a fairly early date. In spite of this, many beets were lost in the outdoor pits, i.e., in the pit with ventilation on sides only, and the regular pits surrounding it, because of high temperatures. Under less favorable field conditions, the differences between the yields obtained from beets stored in the root cellar and outdoor pits, where the storage temperature depends largely on the outdoor temperatures, and the beets stored in cold storage, where the storage temperature can be kept constant, may be even greater than the differences observed above. If this investigation were conducted during a year in which field conditions were unfavorable for early planting, differences between yields from beets stored in a root cellar, where storage temperatures can only partially be controled, and the outdoor pits might be considerably less.

Although the economic aspects of storing beets for seed production purposes were not considered in this investigation, it must be borne in mind that a storage method to be practical must be economical. Further investigation would be necessary to determine the costs of the various methods of storage. When the labor costs of constructing pits and removing beets from them are carefully considered, it is believed that they will be found to be higher per pound of seed produced than the costs per pound of seed produced from beets stored in the root cellar and cold storage.

The above data and discussion would, in the opinion of the author, eliminate outdoor pits as a method of storing beets for seed purposes if cold storage or root cellar storage were available. If it were necessary to use pit storage, the somewhat larger (not significant) yields obtained from beets stored in the pit ventilated in sides and bottom and from the pit with one half the covering of the check would indicate that pits should be well ventilated and not overcovered. The amount of covering would necessarily vary with the outdoor winter temperatures of the locality. Since the yield from beets stored in the soiless pit was less than the yield obtained from those stored in the check, the use of soil about beets in pits is considered advisable.

The secondary object of this problem was to determine whether small beets stored in cold storage would produce as much seed per plant and per acre as the larger beets. The data presented would indicate this to be true, although only a limited number of beets were used. As three times as many small beets can be stored in the space required for the larger beets, the storing of small beets in cold storage would materially reduce the storage costs.

Because of the limited amount of beets stored in cold storage with peat moss covering or with no covering, no conclusive data was obtained. A lighter covering material for storing beets in cold storage would facilitate handling.

No attempt was made, in this investigation, to over-winter beets in the field. Later investigations may prove this possible in certain select localities in the Northeast.

SUMMARY

During the fall and winter of 1941 and 1942, fall grown Detroit Dark Red garden beets were stored in cold storage, a root cellar, and in outdoor pits with varying amounts of covering, ventilation, and soil surrounding the beets. Storage temperatures in the outdoor pits and the root cellar were taken with a galvanometer and thermocouples. The beets were taken from the pits in the spring and graded and planted. Field notes and seed yields records were taken during the summer of 1941. Seed yield and stand data were analysed by analysis of variance and covariance to determine the significance of the data obtained.

The use of the galvanometer and thermocouples for taking temperatures in outdoor pits and root cellars was found practical in good weather.

Freezing injury of beet crowns was observed in outdoor pits whose lowest temperature was 30° F. Freezing injury to beet tissue was observed in outdoor pits whose lowest storage temperatures were 26-27° F. These temperatures lasted approximately three weeks.

Heat injury occurred in outdoor pits whose storage temperatures were above 45° F. for approximately two months.

Dry rot was observed on the tap roots of beets stored in the pit with no soil about them.

Better stands, more vigorous seed stalks, and more

uniform growth were made by beets stored at 33° F. in cold storage and at 38.8° F. in the root cellar.

Significantly better stands and yields per plant and per acre were obtained from beets stored in the root cellar and cold storage.

A greater per cent of rosette seed stalk growth, i.e., seed stalks which had several equal stems instead of a single main stem, was produced by beets stored in outdoor pits. This was thought to be due to the higher storage temperatures observed in the outdoor pits.

No significant seed yield differences were found between beets stored in the root cellar and cold storage, or between the seed yields of beets from the various pits.

Seed yields decreased as the storage temperature increased when the data from pits showing no storage injury were not considered. Better yields (differences not statistically significant) were obtained from beets stored in moderately covered and well ventilated pits.

Satisfactory yields were obtained from small beets, averaging 1.8 inches in diameter, stored in cold storage, indicating that further investigation may prove them suitable for seed production purposes.

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LITERATURE CITED

1. Burrows, G. (Seed Grower, Ontario, New York.) Correspondence. 1942.

2. Chroboczek, E. A Study of Some Ecological Factors Influencing Seed-Stalk Development in Beets (Beta vulgaris L.) Cornell University Ag. Exp. Station Memoir 154. 1934.

3. Cox, J. and Starr, G.E. Seed Production and Marketing. John Wiley & Sons, Inc. New York. 334-344. 1927.

4. Gaskill, J.O. and Brewbaker, H.E. Storage of Sugar Beets Under Conditions of High Humidity and Low Temperature. Am. Soc. of Agronomy. 31:109-115. 1939.

5. Rose, D.H., Wright, R.C., and Whitman, J.M. The Commercial Storage of Fruits, Vegetables, and Florists' Stocks. U.S.D.A. Circ. 278:6. 1942.

6. Vincent, C.C. and Longley, L.E. Vegetable Seed Production in Idaho. Idaho Ag. Exp. Station Bull. 140: 7-11. 1925.