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H. O. Werner

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LINCOLN, NEBRASKA
FEBRUARY, 1949
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Much variation in time of emergence of plants has been observed within lots of Nebraska seed potatoes planted in the South during the winter. In large storage bins in western Nebraska the end of the dormancy period of tubers in various parts of the bin, as determined by the appearance of sprouts, may vary from January to May. It has been surmised that differences in temperatures and perhaps other conditions in various parts of the bin may account for such variations. In the winter of 1941-42 an experiment was conducted to determine the extent to which the position of potatoes within a bin would affect the time and rate of sprout growth. This was determined by removing the potatoes from storage and promptly placing them under identical conditions in sprouting rooms held at constant temperatures, or by planting them in the South.

STORAGE PROCEDURE

Sixty slatted crates (50-pound capacity) of Triumph potatoes were placed among the bulk stored potatoes in a bin in a modern trackside warehouse at Gering, Nebraska, as it was being filled on October 8 and 9, 1941. This bin was located along the north side of the driveway and near the middle of the cellar. It had double ventilated walls on each side and a ventilated rear wall. The wall spaces, which were open at the top, were supplied with air at the bottom by means of a triangular duct which extended along the floor at the base of the side walls from the driveway to the rear and along the base of the rear wall (Figure 1). The capacity of the bin when filled was about 1,200 bushels. The inside of the bin was 9 feet, 6 inches wide, and 20 feet from front to rear. The potatoes were piled about 11 feet high to within 3 feet of the flat ceiling. The rear outside wall was of concrete. The outside grade line was about 2 feet below the top of potatoes in the bin (when filled). The potatoes were placed directly on the ground floor.

1 The author is indebted to the Nebraska Certified Potato Growers Non Stock Cooperative for providing storage facilities; to H. A. McLean, the Cooperative's branch manager at Scottsbluff, for excellent cooperation and to A. D. Edgar of the USDA for installing and reading thermocouples.

2 The field work in Alabama was conducted at the Gulf Coast Branch Experiment Station, near Fairhope, by Otto Brown, superintendent. Theodore Wright and Frank Garrett were in charge of the test. The plant emergence notes and harvest time records were procured by them.
Crates of potatoes were placed among the bulk potatoes on the floor and at 3, 6, 9 and 10 feet above the floor (Figure 1). The tops of the crates in the top layer were on a level with the potatoes in the top of the bin. At each level one set of four crates was placed along the rear of the bin, one set halfway to the rear and a third set was along the front of the bin. In each such set one crate was placed along each wall and two were placed adjacent to each other halfway between the walls. Each crate was weighed before and after filling just before it was placed in position in the bin. Thermocouples were placed in nine positions in the bin for the periodic readings recorded in Table 1.

Air which was blown into the driveway at one end by a thermostatically operated fan was exhausted at the other end of the cellar through the ceiling. This cellar was kept warm the first two weeks to expedite healing of tuber wounds that had occurred during har-
vesting. Beginning October 25 the cellar was cooled rapidly but it was never cooled as much as was possible or desirable. This bin was emptied on January 22. The adjacent bin to the west was emptied on January 5, the one to the east on December 10.

**EXPERIMENTAL RESULTS**

The temperatures recorded were higher than occur in some farm cellars but were lower than in many large cellars used for storing seed potatoes (Table 1 and Figure 2). The temperature in the coolest parts of the bin (the rear wall and front bottom), never was below 41 ° F. The warmest part of the bin was the middle portion of the upper half where the temperature was 68 ° on October 20, about 52 ° on November 22, 48 ° on January 1 and 46 ° and 47 ° on January 19 (Table 1). The temperature along the side walls was generally 3 ° to 5 ° lower than in the middle of the bin. The front portion of the bin was generally 2 ° to 5 ° cooler than the rear part except during periods of meager ventilation, when there was little or no difference. The temperature midway between front and rear was 3 ° to 10 ° higher than the front part of the bin. The driveway temperatures averaged

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*For positions of crates see Figure 1.
1st number = layer of crates, 1-bottom, 5-top.
Letter = longitudinal section, M-middle, E-east, W-west portions of bin.
Last number = depth in bin, 1-by rear wall, 2-halfway, 3 by front of bin.
1 2M2, placed 1 foot above top of crate 2M2, 1 foot below bottom of 3M2.
2 Along west wall. Position comparable to 1E2.
3 Halfway between 1M1 and 2M1, 2 feet from floor, 1 foot from north wall.
4 Immediately beneath 4M1.
Temperature October 25 - Middle Longitudinal

Temperature January 19 - Middle Longitudinal

Fig. 2.—Longitudinal section through the middle of the bin showing the position of the various crates of experimental potatoes, the location of thermocouples and temperatures observed with them, and isothermal lines indicating regions of uniform temperature. The chart at the top shows situation on October 25 at the time of highest observed temperatures. The chart at the bottom shows the situation on January 19 at the time of the lowest observed temperatures. (This was 3 days before emptying the bin.)

7.8° lower than those in the center top portion of the bin. Even at the close of the storage period the middle of the bin was 3° to 6° warmer.

When the bin was emptied the mean weight loss in the 60 crates was found to have been 3.78 per cent. The region of greatest weight
Fig. 3.—Weight loss from October 8 to January 19 of potatoes in various parts of the bin. Above, the middle longitudinal section; below, along the side walls.

Loss was the front upper portion in the middle longitudinal section (Figure 3). Losses were also high in the front bottom, and halfway up along the rear wall. A region of relatively low loss extended from the front about 2 to 5 feet from the floor diagonally across to the rear top portion. Losses were least in the middle of the bin from the floor to the 5th foot. Along the side walls losses were greater than through the middle and seemed to be greatest in a zone extending diagonally from the upper front to the center (Figure 3).
When the bin was emptied sprouts were present on 20 to 25 per cent of the tubers from crates in the top central part of the bin, on 10 per cent of those along the floor and on about 5 per cent of those along the front and rear walls in the middle portion (Figure 4). Along the side wall 12 per cent were sprouting in the top crate halfway between front and rear and a few were sprouting in front and rear top crates. There were no sprouts elsewhere.

The crates of potatoes located along the east wall and the eastern crate of each pair through the middle were sent to Lincoln by express, arriving on January 24. Those from the west half were sent to southern Alabama by heated refrigerator car on January 29, arriving there on February 4.

**SPROUTING TESTS IN LINCOLN**

On the day of arrival at Lincoln, 50 medium size tubers from each crate were weighed and placed in baskets (five baskets of 10 tubers for each crate lot) which were placed on slatted shelves in a room held at 50°F. Another set of 50 tubers was weighed and placed in a room held at 75°F. Constancy of temperature in each room was attained by means of thermostats, and the fans kept the air in constant circulation. At intervals of 2, 3 or 4 days all these potatoes were inspected to note the number sprouting by each date. At the end of 50 days (March 15) the sprouts were removed, counted and weighed.\(^3\)

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\(^3\) Experience has shown that although this is probably the best practical method of observing the completion of the rest period of the potatoes in various parts of a large bin it is subject to numerous errors. In taking 50 tuber samples from a crate of about 125 tubers the sampling may not always be random. The mean value for sprouting time may be altered several days
The temperature of 50° was chosen because it is close to that prevailing when potatoes are planted in the South. The temperature of 75° was used because it is typical of temperature in retail stores or homes.

Sprouting in the 75° room was not only much more rapid than in the 50° room but there was less difference between rapidly and slowly sprouting sets of tubers (Figure 5). Of all the potatoes tested at 75°, 50 per cent began to sprout by 6 days in contrast with slightly less than 11 days for those held at 50°. Most of the ensuing discussion concerns the sprouting data procured at 50°.

by taking more tubers from one end than the other. This is more likely to be important with crates located along the rear wall where temperature differences within the 2-foot length of the crate are relatively greater than in the central portions where temperatures vary less. The sprouting of occasional tubers in a lot may be accelerated or delayed by slight mechanical injuries, scab lesions or some virus or other disease. Finally it is difficult to decide at what stage an elongating bud becomes a sprout. The criterion used for differentiation was an estimated elongation of 1½ to 2 millimeters. To diminish the various errors that might occur with this visual estimation, each sample was divided into five subsamples of 10 tubers that were placed in different parts of the storage room. Although the plotting of the data taken at 3-day intervals produces relatively smooth lines or curves, the few irregularities indicate that sometimes important changes occurring between observation dates were not detected. The accumulation of several of these errors in certain directions might easily have been responsible for some of the aberrant data from a few crates of potatoes. Although these few instances are annoying they do not invalidate or seriously jeopardize the general conclusions.
The sprouting records for potatoes from each of the crates in different portions of the middle longitudinal section of the bin are shown for ready comparison in two sets of graphs. One set provides for direct comparison of crates in the same vertical line at different levels (Figure 6), and the other for comparison of those in direct horizontal lines on the same level (Figure 7).

A series of diagrams showing isocurves are useful in portraying the sprouting characteristics of potatoes from crates in all parts of various planes or sections within the bin as well as potatoes from the portions between the crates. The percentages of tubers from the middle longitudinal plane that were found to be sprouting at 50° F. on the 11th day are shown in Figure 8. It is generally conceded that the rest period can be considered completed when 50 per cent of the tubers have produced sprouts. This time when 50 per cent of the tubers were sprouting was determined for each crate from graphs such as are shown in Figures 6 and 7. A series of isocurve diagrams showing when sprouts were found on 50 per cent of the tubers has been prepared for the following planes: longitudinal, through the middle and 1 foot from the east wall (Figure 10); 10th, 7th and bottom foot levels (Figure 11); and front, middle and rear cross section planes (Figure 12). As these charts present a relatively complete picture of the sprouting status of tubers in all parts of the bin, comments will be limited to a presentation of general principles and a few details concerning several portions of the bin.

Sprout growth occurred most quickly with tubers from the upper central part of the bin and most slowly with those along the peripheral portions—that is, the walls and floor. In general the tubers in various parts of the front half of the bin sprouted slightly earlier than those at the same distance from the center in the rear half of the bin. In the middle longitudinal plane the sprouting time for tubers increased at the rate of slightly more than 1 day per foot of distance from the center to the rear wall at a height of 6 feet, compared with about 0.8 day per foot from center to front. Tubers from the crate in the center of the floor sprouted a week later than those on the floor along the front and rear walls. With tubers from the front part of the bin the sprouting time increased from top to bottom at the rate of about 0.8 day per foot. Halfway between the front and rear walls it increased from the 8th foot to both the floor and the top. It was

Fig. 6.—Percentage of tubers from crates located in the middle longitudinal plane of the bin that were sprouting by various numbers of days after being placed in the 50° room. Each line shows the percentages for tubers from one crate. Above, crates from front; middle, crates from center; and below, crates from rear of bin. The numbers on each graph represent the height above the floor at which the crates were located in the bin.
Fig. 8.—Percentage of tubers from middle longitudinal section that were sprouting after being held 11 days at 50° F.

Fig. 9.—Number of days for sprouts to develop on 75 per cent of the tubers from the middle longitudinal section when held at 50° F.

Fig. 7.—Percentage of tubers from crates, located at different levels in the middle longitudinal plane, that were sprouting various numbers of days after being placed in the 50° room. Above, crates from top (11th foot); middle, crates from 7th foot; and below, crates that were on the floor.
found that those from the top (11th) foot were about 5 days later than those from the 10th foot. Along the rear wall there was little difference from top to bottom.

Tubers from along the side wall sprouted more slowly and more uniformly than those in the middle longitudinal plane. This difference between middle and side wall potatoes was least in the front foot but greatest in the cross section halfway between the front and
the rear walls where the sprouting difference of 9 days in the 7th foot amounted to a delay of about 3 days per foot. In this halfway plane large bands of potatoes from top to bottom sprouted at the same time. The values for tubers from two of the rear corner crates (1st and 9th feet) seem aberrant and are suspected of being in error (see footnote, page 8).

Tubers from the bottom and top levels were the slowest to sprout but also the least variable. Those from the 7th and 10th feet sprouted most quickly but there was considerable difference among those from different parts of the layers. Tubers from any of these levels located in concentric elliptical-shaped bands sprouted at the same time. The bands were widest toward the front and narrowest along the side.

The slower sprouting of tubers in the top 6 to 12 inches of the bin was probably due to the cold air that moved in over the bin from

![Diagram](https://via.placeholder.com/150)

Fig. 11.—Isocurves showing the number of days required at 50°F. for sprouts to develop from 50 per cent of the tubers that had been stored at three different levels in the bin. A, 10th foot level; B, 7th foot level; and C, bottom of bin (actually 6 inches, i.e., half the crate height, above the floor).
Fig. 12.—Isocurves showing the number of days required at 50°F. for sprouts to develop from 50 per cent of the tubers that had been stored in the east half of three different cross section planes in the bin. A, front; B, halfway between front and rear walls; and C, rear wall sections. These front and rear planes were actually 1 foot (half crate length) in from the walls.

Fig. 13.—Weight of sprouts at close of 50 days in test rows at 50°F. as per cent of the weight of the tubers when they were removed from the various portions of the middle longitudinal section of the bin.
the cold rear wall. Apparently the air movement behind the false wall along the rear and through the triangular ducts was not fast enough to conduct all the heat that was lost through the exposed wall when air circulation depended entirely on gravity.

Sprouts were removed from all tubers and counted on the 50th day in the 50° room. Generally the slowest sprouting tubers had the fewest sprouts and those sprouting first had the most. However, differences were small and subject to great error because of the difficulty in differentiating between single sprouts and basal axillary branches.

Sprout weight is considered a useful index of the vigor of growth and eventual yield from any lot of tubers, and more dependable than sprout numbers. When sprout weights were calculated as the percentage of the weight of the test lots when put into storage they were found to vary from 0.26 per cent with the crate along the floor in the middle front of the bin to 1.7 per cent in the center of the bin (Figure 13). The isocurve pattern for sprout weight was very similar to that for plant emergence and temperature.

FIELD TESTS IN ALABAMA

Although great differences do exist in the degree of dormancy of seed potatoes when they are removed from various parts of large bins, it remained to be determined whether they cause significant differences in the time and rate of plant emergence when the potatoes are planted in the South. From other tests and general experience it is recognized that these differences in degree of tuber dormancy might be reduced before the tubers are planted because of more extensive aeration of the potatoes after sacking or the warming that generally occurs in transit and in the South while the potatoes await planting. On the other hand the soil conditions prior to plant emergence and the differences in temperature in various parts of a refrigerator car might increase the differences.

The 30 crates in the western half of the bin were included in a heated refrigerator car shipped to southern Alabama on January 29 that arrived there February 4. On February 9 six 49-seed-piece single-row plots were planted at the Gulf Coast Branch Experiment Station at Fairhope with potatoes from each crate. During the six weeks following planting the temperature fluctuated between 46.2° and 52.8° F. During March and early April an excessive amount of rain occurred but after mid-April the weather was relatively dry.

The plant emergence record for the potatoes from each crate was procured by counting all plants in all plots at intervals of 3 to 5 days starting March 15. Because of the cold wet soil, plant emergence was relatively slow and the final stands were not as good as usual. On April 6 final stands for potatoes from various bin positions ranged
from 75.5 to 92.5 per cent, with an average of 82.4 per cent for the potatoes from all positions. The isocurves for percentage of plants emerging by the 45th day after planting are shown in Figure 14 for the potatoes removed from the middle longitudinal section.

The differences in time and rate of emergence of plants from potatoes from different bin positions were very similar to those occurring with the lots of potatoes from comparable positions in the other half of the bin when they were tested in the 50°F room at Lincoln, Nebraska. Tubers from the upper central portion of the middle longitudinal section emerged most rapidly, as measured by calculating number of plants emerging as per cent of seed pieces planted (Figure 14). By the 45th day 40 to 45 per cent of the seed pieces from the potatoes in the central part of the bin produced plants. Then the percentage from the front and rear wall crates was 24 to 33 per cent. Tubers that had been along the west wall of the bin produced plants more slowly than those that had been in the middle portion, but there was less difference between the tubers in various positions along the west wall.

The isocurves for number of days required for plant production by 50 or 75 per cent of the seed pieces from various parts of the bin showed essentially the same pattern as those for emergence by any given date.

**FIG. 14.—Percentage of seed pieces of tubers from various parts of the middle longitudinal section of the bin from which plants were through the ground on March 23, 1942, 45 days after planting in replicated plots at Fairhope, Alabama.**
EFFECTS OF BIN POSITION ON SEED POTATOES

The mean plant size derived from estimates of size of individual plants in the normal rows of each lot was greatest from the plants that emerged earliest. Thus by any given date those from the center of the bin produced the largest plants and those from near the walls and floor the smallest plants.

Rate of emergence, stand of plants and yield were correlated with each other as shown by charts in which the per cent emergence by 50 days is plotted against final stand (Figure 15) and against total yield (Figure 16), and final stand is plotted against total yield (Figure 17).

This leads to the conclusion that, in spite of the time elapsing between removal from the bin and planting time and the long slow emergence in cold wet soil, seed pieces from the central part of the bin produced the earliest plants and those from the peripheral parts of the bin, especially from along the rear wall, were the last to produce plants. Furthermore, because of the correlation between emergence rate and per cent of final stand which in turn was correlated with yield, the potatoes from the central part of the bin were most productive and those from the peripheral parts were least productive.
The plant production history of the seed potatoes sent to and planted in Alabama was essentially the same as that of the potatoes from crates in corresponding positions in the other half of the bin that were sent to Lincoln for sprouting.

SUMMARY

1. Triumph potatoes were stored from early October to mid-January in a large, fairly well ventilated bin in a tracksid warehouse to determine the time and rate of sprouting of seed potatoes stored in slatted crates in various parts of the bin. This was determined after removal from the bin by (a) placing 50 tuber samples from each crate at both 50° F. and 75° F., and at intervals of 3 or 4 days counting
the number of tubers from which sprouts were growing, and by (b) planting 6 plots of 49 hills each in southern Alabama and there procuring notes on rates of plant emergence.

2. The temperatures in various parts of the bin, as determined by means of thermocouples, were found to differ as much as $12^\circ$ F. when cooling began in October to as little as $3^\circ$ or $4^\circ$ in midwinter. The warmest portion was a large region in the upper central part of the bin. The coolest portions were along the walls (especially the rear wall) and along the bottom of the bin.

3. When the bin was emptied on January 22 some tubers in the warm central portion of the bin were sprouting but others were dormant.

4. The time of sprouting was correlated very closely with the temperature in various portions of the bin. In the $50^\circ$ F. testing room 50 per cent of the tubers from the upper central part of the bin were sprouting within 3 days, but about 10 or 11 days were required for the same amount of sprouting in those from the central

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Fig. 17.—Correlation between percentage of final stand of plants and total yield as bushels per acre in plots at Fairhope, Alabama in 1942.
part of the floor and the upper part of the front wall and about 17
days for those along the rear wall. Those along the side walls,
especially in the upper part of the bin, sprouted several days later
than those on the same level in the middle longitudinal section of
the bin.

5. When placed at 75° F. the tubers sprouted 3 to 5 days more
quickly than at 50° but the differences due to position in the bin
were the same at both temperatures.

6. The weight of sprouts calculated as per cent of original weight
of tubers placed in the test room was closely correlated with the
temperature and rate of sprout growth in various parts of the bin.

7. With potatoes from crates placed in various parts of the bin
and planted in Alabama in early February the rate of emergence cor-
responded with the sprouting rate in controlled temperature storage
at Lincoln. The potatoes from the central portion produced plants
earlier than those from the cooler portions near the walls and floors.

8. In Alabama field tests there was a close correlation between
early plant emergence, plant size and high yields of early potatoes.