# Changes in Root Weight of Sugar Beets During Their Reproductive Phase

J. M. Fife and Charles Price[1]

Under some conditions sugar beet roots grow very little during the reproductive phase and under other conditions they may grow appreciably. Pultz (1)[2] in his study of field-overwintered plantings of U.S. No. 1 (an easy bolting variety) conducted near St. George, Utah, found little increase in root weight of the unthinned sugar beets after seed production began. The plantings were made August 23 and September 15 and included two fertility levels. The same results were obtained irrespective of planting date or whether or not the plants were fertilized with nitrogen. In other tests by Pultz, sugar beet plants that were thinned to single plants, standing 12 inches apart in the row, showed considerable increase in weight of roots during the reproductive phase. The increase in weight was greatest in the roots that did not receive nitrogen fertilizer.

The authors' observations also have shown a diversity in plant reactions dependent on conditions. In order to obtain further information, studies have been conducted to determine some of the factors involved.

Sugar beet seed production in the United States is chiefly by the field-overwintering method. Seed fields are planted in the late summer and the small sugar beet plants are left unthinned and undisturbed until the seed is harvested the following summer. In the conventional method, the seed is produced from mother beets or from stecklings. Seed is planted in the spring or early summer; the roots are dug in the fall and stored under cool conditions over the winter. The roots are then transplanted in the early spring in the seed field. Under the conditions of temperature, ordinarily experienced in most seed-producing districts, stored roots and those overwintered in the field acquire sufficient thermal induction to initiate and complete the reproductive phase. The experiments to be reported employed varieties that readily produce seed under the winter conditions of southern California.

## Experiments with Field-Overwintered Sugar Beet Roots

In an experiment conducted in 1943-1944, an annual type of sugar beet (SL 2850) was grown at two fertility levels. The plot held at the lower-fertility level received no barnyard manure but 800 pounds of ammonium sulphate was applied. For the higher-fertility level, barnyard

[1]Biochemist and Agronomist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture.

[2]The numbers in parentheses refer to literature cited.

manure was applied to a plot at the rate of 20 tons per acre, and, in addition, ammonium sulphate was applied at the rate of 1,800 pounds per acre.

The seed was planted September 27, 1943, on 12 single-row beds, 20 inches apart. Each row was 84 feet long. The plants were thinned at the 4- to 6-leaf stage to stand approximately 8 inches apart in the row. Roots were dug from the high- and the low-fertility sections of the plot at intervals from the time the roots were thinned until the seed was mature. The roots were topped at the lowest leaf scar and weighed individually. The first bolters appeared the last week in March, 1944, and by April 22 all of the plants had produced seedstalks. These averaged 38 inches high.

To obtain more reliable data on root weights, large numbers of roots were dug and weighed individually at four criterion periods, December 17, January 19, March 23, and June 29 (harvest time). The numbers of roots taken at these dates were 207, 145, 236, and 423, respectively. Samplings at other dates (see figure 1) consisted of 20 roots. In view of the fact that no significant differences were found between the weights of the roots as taken from the two fertility levels, only mean root weights will be reported.

The growth of the roots from the time they were thinned until the seed was harvested, as revealed by the samplings, is shown in figure 1. Observations made during the test and the meteorological records indicate that the conditions were such as would promote complete fructification

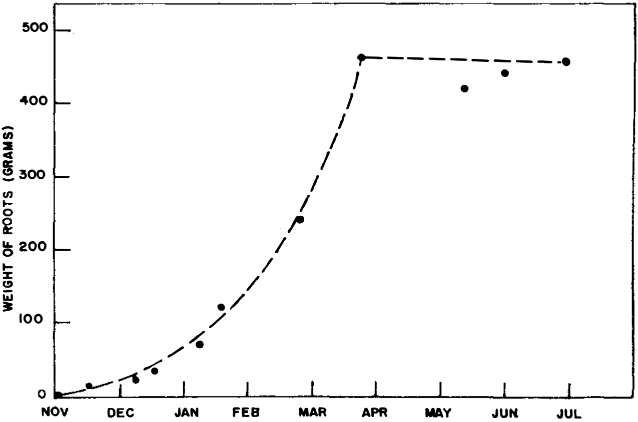


Figure 1.—Root weights of field-overwintering sugar beets (SL 2850) from the thinning period until harvest. Data were obtained from a series of samplings of the 1943-1944 experiment. The smooth curve shown was not fit to the data and therefore only indicates the trend.

of the variety SL 2850. The data as given in figure 1 show, therefore, that these roots receiving sufficient photothermal induction to insure production of seedstalks abruptly stopped growing when the reproductive phase began.

Corroborative evidence of the same general character was obtained in a replicated test conducted in 1944-1945 with the sugar beet variety U.S. 33. This variety, although requiring more photothermal induction than SL 2850, is known as an easy bolter, and its seed production under California conditions usually involves a high population of the seed field.

An experiment on sugar beet seed production was set up consisting of manure versus no-manure treatments upon which were superimposed three levels of nitrogen as obtained by applying sodium nitrate in differential amounts, several times during the season. For the three levels set up, the applications totaled, as acre rates, 380, 800 and 2,200 pounds for the low, medium and high-fertility levels, respectively. The plots were 8 rows wide and 35 feet long, and were arranged as a 6-times replicated randomized block. The seed was planted August 23, 1944, and the plants thinned to a distance of 6 inches in the row at the 4- to 6-leaf stage. The first seedstalks appeared the last week in March, 1945. Bolting counts made during the early part of the reproductive phase showed that at least 95 percent of the plants produced mature seed.

For studies on the rates of growth of the roots, a series of 10 samplings was made over the entire experimental area. On February 9, a total of 180 roots, 5 per plot, was taken to determine the average size of the roots at the time when rapid growth was just beginning to be resumed in the spring and well before seedstalk formation began. There was no significant difference in weights of roots from the different fertility levels; in subsequent samplings no significant effects attributable to fertility levels were found. For simplicity, the data are combined and reported as simple averages for all treatments.

Samplings were made during the reproductive phase, 2 roots being taken each time from the plots making a total of 72 roots (36 from manured, 36 from non-manured portions). After bolting was well advanced, only those plants producing normal seedstalks were sampled; at the last sampling when the seed was matured, all the roots of the center rows of each plot that had bolted were weighed. This sampling involved approximately 100 roots from each plot, making a total of approximately 3,600 roots. The results of the experiment are shown in figure 2.

From February 9 to March 16, the roots increased in weight approximately 75 percent. From March 16 until the seed was harvested, no significant change in the weight of the roots occurred. The solid line (figure 2) is the linear regression line computed from the data on root weights from the samplings on March 16, just prior to bolting, to June 23, when the seed was harvested. As in the previous test, the sugar beet roots, that had acquired sufficient thermal induction for complete bolting, did not make significant amounts of growth during the reproductive phase.

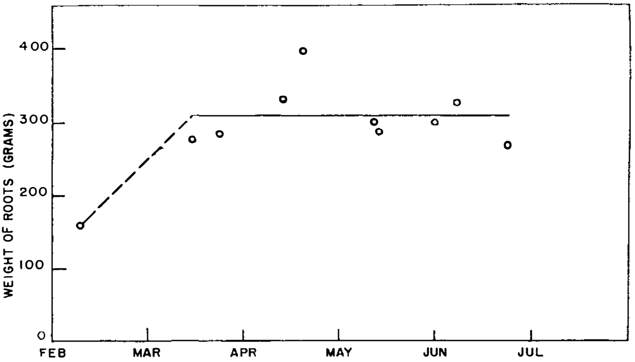


Figure 2. Average root weights of field-overwintered plants of the sugar beet variety U.S. 33 prior to and during the reproduction phase in the experiment conducted in 1944-1945. The broken line indicates the trend before growth ceased, the solid line is regression line computed from the data for March 16 to June 23.

## Experiments with Transplanted Sugar Beets

Approximately 1400 roots were obtained from Salt Lake City, Utah.[3] The seed to produce the stecklings was planted in a seed plot July 31, 1942, and the roots were dug January 14. The small stecklings were taken from unthinned sections of the plot whereas the large stecklings were dug from thinned sections of the plot. Mother beets included in this study were dug in the fall from thinned plots which had been planted in the spring of 1942. These roots were stored in a root cellar until transplanted in the spring. One hundred roots ranging in size from 15 to 45 grams with a mean weight of 29.1 grams, were divided into 20 five-root groups, the roots in each group having approximately the same weight. A similar number of roots with a mean weight of 110.6 grams and a third group of large roots having a mean weight of 1,103 grams were also divided into 20 five-root groups. The test was conducted at two nitrogen-fertility levels. The lower of these appeared to be adequate for normal growth because the higher-fertility level did not increase the growth of the roots. The results for the two fertility levels have been combined, and only mean values are reported. The 5-root groups of the small, medium and large beets were transplanted February 2, 1943, in a randomized-block arrangement on the high and low-fertility section of the plot. When the seed was mature all the roots of the small and medium-sized beets that had produced mature seed were weighed individually and the mean increase in weight calculated, using as the weights at transplanting time the mean values 29.1 for the small roots and 110.6 for the medium-sized roots. The large beets had been

[3]These sugar beet roots were furnished by Bion Tolman, formerly of this Division.

weighed individually and the weight recorded on the root at transplanting. They were again weighed individually and the increase in weight determined for each root. The gain in weight of the transplanted roots during the reproductive phase and the bolting data are shown in table 1.

**Table 1.** Increase in weight of transplanted sugar beet roots (U.S. 22) during the reproductive phase in relation to root sizes and to the percentages of roots bolting and producing seed.

| Year and place roots were grown | Mean weight of roots at transplanting | Average gain in weight of roots | | Plants bolting | Plants producing seed |
|---|---|---|---|---|---|
| | grams | grams | percent | percent | percent |
| 1943—Salt Lake City, Utah | 1103 | 217 | 19.7 | 78 | 68 |
| | 110.6 | 134 | 121 | 72 | 68 |
| | 29.1 | 139 | 478 | 55 | 44 |
| 1945—King City, California | 1064 | 110 | 10.3 | 100 | 93 |
| | 841 | 89 | 10.6 | 99 | 97 |
| | 643 | 71 | 11.0 | 100 | 97 |

Another test conducted in 1945 is also shown in table 1. Sugar beets (U.S. 22) were taken from King City, California, and stored for a period under conditions favorable for thermal induction to take place. These roots were divided into groups of three sizes, each containing 120 roots. The mean weights of the roots, comprising the three different sizes, were 643, 841 and 1,064 grams. The roots were weighed individually and the weight recorded on them at the time of transplanting. The roots of each size class were subdivided into 12 ten-root groups so that each group had about the same range in root size and approximately the same total weight. Six 10-root groups of each size class were transplanted in a randomized block on each of the two nitrogen-fertility levels. When the seed was mature the roots were topped at the base of the seedstalk and weighed individually. The increase in weight of each root was determined by reference to its initial weight. The differential fertilization proved to have no effect on the root growth during the reproductive phase, consequently mean values only are reported.

In these two tests the increase in weight of the transplanted roots during the reproductive phase was least when thermal induction was sufficiently complete so that a high percentage of the plants produced seed. In the 1945 test, in which 93 to 97 percent of the plants produced seed, the roots increased in weight approximately 10 percent. In the 1943 test, in which only 44 percent of the roots of very small size produced seed, the increase in weight that occurred in the roots producing seed was 478 percent. The very small roots that did produce seed bolted later than the larger roots, and increased more than four fold in weight. The gain in weight of the medium-sized roots (110.6 grams) also was striking.

A third test was conducted with transplanted roots during the season of 1946-1947 to determine the weight increase of sugar beet roots during the reproductive phase, the roots being of the same age but differing in size. A planting of the variety U.S. 33 to supply the roots for the test was made at Riverside, California, February 13, 1946. The plants were grown under the same environmental conditions except for space allotments. Some plants had wider spacings in the rows and consequently made more growth. On December 15, 180 roots ranging in weight from 29 to 759 grams were taken for the test. The roots were segregated by weight into 36 five-root groups. Each group consisted of roots of very nearly the same weight. The roots were packed in moist sphagnum moss and stored for thermal induction at 40° F. for 86 days. The roots were transplanted on March 13, 1947, in a field plot in which a high level of fertility was maintained. After the seed was mature, the plants were dug and weights of roots again determined. In figure 3, the mean increase in root weight for the 36 five-beet group is plotted against the corresponding root weight at transplanting. The regression line for gain of weight of roots on the weight of roots at transplanting is shown. The correlation coefficient, —0.655, is highly significant. It is evident from this test that the smaller the roots were at transplanting, the greater was their increase in weight during the reproductive phase.

### Discussion

The results obtained with field-overwintered plants of easy bolting varieties, in which photothermal induction was apparently adequate, indicated that root weights increased about as would be expected until the reproductive phase started when growth essentially stopped. The curves indicate that the change was abrupt. The regression line as determined from the data in 1944-1945 test with U.S. 33 showed that with 95 percent of the plants producing seed, the increase in weight after fructification began was not significant.

Tests with transplanted beets showed that the size of roots may be a factor influencing increase in root weight after fructification begins, but here also the degree of thermal induction seems a controlling factor. Roots ranging from 643 grams to 1,064 grams showed essentially the same percentage of gain in root weight when thermal induction, as revealed by the percentage of plants going to seed, apparently was nearly complete. On the other hand, small roots (110.6 grams average) and very small roots (29.1 grams average) whose thermal induction was such that only 68 and 44 percent of the plants, respectively, produced seed, gained respectively 121 and 478 percent in weight over the transplanting period weight. These data were based entirely on plants producing mature seed. Observations were made that the small roots that produced seed bolted more slowly than the larger roots.

The extensive experiment in which presumably the thermal induction was adequate, and in which the gain in weight of roots was found to be negatively correlated with root weight at transplanting time, probably can be interpreted in light of the preceding experiments.

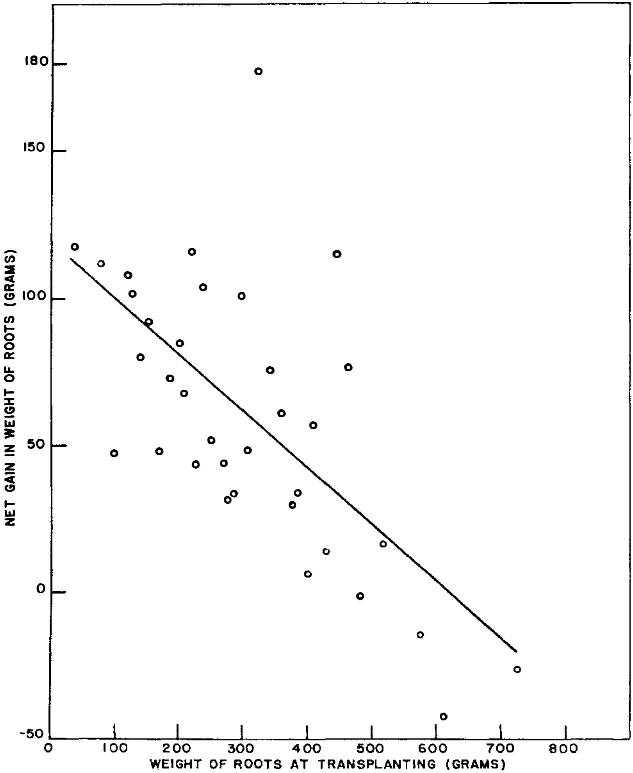


Figure 3. Gains in root weight during the reproductive phase are plotted against the corresponding root weights at transplanting time. The regression line is shown. The data are taken from the 1946-1947 experiment in which roots were stored 86 days at 40° F. prior to transplanting.

The fact that in a test where the degree of reproduction indicated inadequate induction there was striking increase in weight of roots and that the increase appeared to exhibit an inverse trend to the degree of thermal induction, suggests a relationship between thermal induction including the reactions it brings about and the continuance or discontinuance of vegetative development.

The fact that in the 1946-1947 test with transplanted roots where extensive thermal induction was given and all the plants bolted, the smaller beets in general showed more increase in root size than did the larger beets may indicate that there is a size factor influencing the acquisition of thermal induction by sugar beets.

## Summary

Sugar beets of easy bolting type (SL 2850 and U.S. 33) were grown for seed production by the field-overwintering method under conditions that brought about essentially complete reproduction. The roots of these sugar beets did not continue to increase in weight after the reproductive phase began. By contrast, sugar beet roots in which the degree of reproduction indicated inadequate thermal induction increased in root weight, the greatest increase occurring in small roots. In another test, extended thermal induction treatment was given prior to transplanting the roots for seed production. All plants produced seedstalks. Some gain in root weight occurred after transplanting. There was a significant negative correlation between the gain in weight and the root weight at time of transplanting. This may indicate that root size is an important factor in the thermal induction process.

## Literature Cited

(1) PULTZ, L. M.
1937. Relation of nitrogen to yield of sugar-beet seed and to accompanying changes in composition of the roots. Jour. Agr. Res. 54 (9): 639-654.