EFFECT OF MULTIPLE-PLANT HILLS
ON YIELD AND QUALITY OF SUGAR BEETS

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A number of experiments with sugar beets involving different populations of plants and different stand patterns have been conducted at Fort Collins, Colorado* during the period 1938 to 1945. These were summarized at the 1946 meeting of the American Society of Sugar Beet Technologists. The general conclusion drawn from these data is that under the conditions of the tests and with rows 20 inches apart, yield of sugar beets is primarily dependent on the number of hills in the stand, the maximum stand being about 100 hills per 100 feet of row. Additions to the plant population as brought about by 2-plant of multiple-plant hills occurring among the single-plant hills had little effect on yields. The hill was the population unit determinative of yield regardless of the number of plants in the hill.

From the data summarized a year ago it was possible to compare directly the yields from full stands of single plant hills with the yields from full stands in which a portion of the hills were of 2- or multiple- plant type. Yields of a number of partial stands containing 2-plant and multiple-plant hills were compared by analogy with the probable yields of similar stands of single-plant hills, but data were not available for direct comparisons of these conditions. In 1946, an experiment was conducted from which such direct comparisons could be made. It is the purpose of this paper to summarize briefly the data from this experiment.

Materials and Methods

This test was conducted on the Agronomy Farm of the Colorado Agricultural Experiment Station adjacent to the town of Fort Collins. The soil is Fort Collins loam, light textured phase. The previous crop was spring wheat for which there had been a light application of trashy barn yard manure. The wheat stubble was irrigated in early fall. Because of shortage of water, the application was not uniform over the field. Following irrigation, about 15 tons per acre of rotted manure was applied and the field was fall plowed. The winter and early spring were exceptionally dry. The appearance of the beet crop at thinning time indicated that subsoil moisture was becoming exhausted in some parts of the field and weed competition on some small areas may have also adversely affected the early growth of the beets on such areas. Recovery and progress of the beet crop after the first irrigation in early

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July was rapid and very good. However, the moderately high variability in the data from this test as revealed by inspection of the results from individual plots and by the relatively high values of the Standard Errors for acre yields of roots and for acre yields of gross sugar may be largely attributable to variability in the effect of these adverse, early season conditions.

The treatments included in the test were 30-, 50-, 70- and 100- percent stands of hills. Stands consisting exclusively of single-plant hills were compared with stands in which 75 percent were single-plant hills, about 23 percent, 2-plant hills, and about 2 percent, 3-plant hills. These comparisons were planned for each of the stand levels. An additional full stand treatment was included in which the blocked initial stand was trimmed with long-handled hoe. The test was set up as a randomized block experiment with six replications. The plots consisted of eight rows, 60 feet in length, with rows spaced 20 inches apart. The inside four rows of each plot were harvested. The kinds of hills and the position of the plant-containing hills and skips in the plots were determined by separate drawings of random numbers for the four border rows and four inside rows of each plot of each treatment.

Sheared seed was planted in late April, but germination did not occur till rains wet the soil in May. A moderately thick initial stand emerged in mid-May. The whole area of the test was blocked with a long-handled hoe to approximately 100 beet-containing-blocks per 100 feet of row. Two-man crews then thinned the plots according to the predetermined stand pattern for each plot. For all the plots, the stands attained after thinning very closely approximated the stands as planned. In the case of the treatment in which the blocked stand was trimmed with long-handled hoe, the final thinned stand on these plots averaged only nine plants more per 100 feet of row than were in the comparable plots in which 25 percent of the hills contained two or three plants. The stand patterns of the two treatments were approximately identical.

The test was harvested in late October. Three 20-beet samples were taken at random from each plot for sucrose determinations. The harvest crew was instructed to save all beets approximately one inch in diameter at the crown. All roots were washed before weighing. No record was made of the small beets discarded, but since plant losses during the growing season from insect or disease attacks were negligible, it is believed that the difference between the counts of plants present immediately after thinning and the counts of harvested roots is a good indication of the number of plants that failed to produce roots of marketable size.

Discussion

Data for hills, plant populations and roots harvested are presented in Table 1. The information is given as percentages of the initial plant populations as planned, except loss in stand between thinning and harvest is shown as percent of the individual initial stand. It should be noted that in all cases the stands of hills of single plants and the stands of hills containing additional plants are approximately equal at each stand level. The numbers of beets harvested show that in all cases in the stands containing 2-plant and 3-plant hills, plants in appreciable number occurred that did not produce roots of marketable size. There were proportionately more of such plants in the 100- and the 70 percent stands of hills than in the 50- and 30 per cent stands of hills.

Acre yields of roots and of gross sugar and the percentage sucrose in the roots are given as 6-plot average in Table 2. In general, equal stands of hills produced approximately equal yields. The two 70 percent stands in this test failed to conform to this pattern, the single-plant hills exceeding the similar stand containing a portion of 2- and 3- plant hills by 1.60 tons of roots and 330 pounds of gross sugar per acre. In the case of root yield, this difference is statistically significant. However, examination of the data from individual plots of these two treatments reveals that two of the plots having single-plant hills and unusually high yields. Furthermore, two of the plots having 2- and 3-plant hills in their stands had unusually low yields and one of these plots is known to have been on a spot in the field that appeared to be suffering severely from drought and from weed competition at thinning time. Pending further evidence from additional tests it seems probable that the differences in this instance are fortuitous rather than real differences.

Table 1: Sugar beet stands. The number of hills and plants per 100 feet of row as thinned, the number of beets harvested per 100 feet of row and the loss of stand from thinning to harvest in percent of thinned population are given. Fort Collins, Colo. 1946. (Data given as 6-plot averages).

Treatment	Thinned stand (100' of row) Hills	Thinned stand (100' of row) Plants	Beets harvested[1] (100' of row)	Percentage of initial plants lost
1. Full stand; all 1-plant hills	99.4	99.4	97.0	2.38
2. Full stand; long-handled hoe thinned	96.0	134.0	111.5	16.79
3. Full stand; 25% double- and multiple-plant hills	96.8	124.9	107.8	13.67
4. 70% stand; all 1-plant hills	69.9	69.9	69.4	0.79
5. 70% stand; 25% double- and multiple-plant hills	70.9	91.4	81.6	10.65
6. 50% stand; all 1-plant hills	50.1	50.1	49.0	2.35
7. 50% stand; 25% double- and multiple-plant hills	52.4	67.4	61.9	8.24
8. 30% stand; all 1-plant hills	31.0	31.0	31.0	0.22
9. 30% stand; 25% double- and multiple-plant hills	33.1	50.7	46.2	8.77

[1] Beets approximately 1 inch in diameter at the crown were saved at harvest.

Table 2: Acre yields of roots, sucrose percentage and gross sugar production in sugar beet population study. 8 row plots, 60 feet long, with rows 20 inches apart and the inside 4 rows of plot harvested. Fort Collins, Colorado. 1946. (Data given as 6-plot averages.)

Treatment	Acre yields Roots (tons)	Acre yields Gross sugar (pounds)	Sucrose percentage (%)
1. Full stand; all-single plant hills	15.57	4,696	15.10
2. Full stand; long-handled hoe thinned	14.88	4,465	15.02
3. Full stand; 25% double-and multiple-plant hills	15.02	4,430	14.76
4. 70% stand; all single-plant hills	14.54	4,208	14.46
5. 70% stand; 25% double-and multiple-plant hills	12.94	3,878	15.00
6. 50% stand; all single-plant hills	12.26	3,472	14.18
7. 50% stand; 25% double-and multiple-plant hills	12.62	3,644	14.44
8. 30% stand; all single-plant hills	9.74	2,642	13.55
9. 30% stand; 25% double-and multiple-plant hills	9.60	2,736	14.26
Mean of test	13.02	3,797	14.53
F value	21.28**	33.96**	4.31**
Difference required for significance (Odds 19:1)	1.38 T.	365 lb.	0.69%
Standard error of the mean in percent of the general mean	3.70%	3.36%	1.66%

The values for sucrose percentage recorded in this test are of particular interest. From the treatments in which the stands were reduced and a portion of the hills were of 2-plant and 3-plant type, higher average sucrose percentages were found in the roots, than were found in the roots from comparable single-plant hills. In the case of the thinnest stand the difference in sucrose percentages is statistically significant. This significant difference, taken with the trend evident in the cases of the 70- and 50 percent stands, indicates that in thin stands additional plants present at 2-plant and multiple-plant hills tend to increase the average sucrose percentage of the crop even though root yield is not likely to be increased by such additional plants.

In general, the results of this test confirm the previous conclusion that the hill is the unit of sugar beet plant population which, in the main, determines the yield of roots. Additional plants present as 2-plant or multiple-plant hills in either full or partial stands of hills will not increase root yield and probably will not materially decrease yields so long as most of the stand consists of 1-, 2- or 3-plant hills. It is obvious that a hill containing a large number of plants may produce no roots of marketable size even though the total weight of all roots in the hill equalled that of normal 1-plant hill.

The conclusion warranted by this test and those of other seasons, namely, that the hill is the unit of population upon which yield of sugar beets depends, is of particular interest in connection with the moves toward complete mechanization of operations in producing the sugar beet crop. It is obvious that machines can never achieve the uniformly spaced, full stands of single-plant hills which have been the goal of hand work and which frequently are attained by skilled farm labor. There is no evidence from these tests that additional plant population, present as 2-plant and multiple-plant hills, will compensate for blank spaces in the stand. On the other hand, there is no evidence from these tests that there will be reduced sugar production when up to a fourth of the hills contain 2 or 3 plants each. Moreover, with reduced stands, it appears probable that the slight reductions in root yield, due apparently to the nonharvest of very small roots, may be offset by a slightly higher sugar percentage of the roots produced in the 2-plant and multiple-plant hills.

Conclusions.

The number of hills of sugar beets on a given area, up to the optimum number of hills for the conditions, bears a direct relation to the weight of roots produced. Additional plants contained in 2-plant and multiple-plant hills in either full or partial stands have little, if any, effect on the total yield of roots

In the case of thin stands of sugar beet hills, the additional plants in 2-plant and multiple-plant hills tend to produce a crop with a slightly higher sugar percentage than the crop from similar stands of single-plant hills.

In machine thinning of the sugar beet crop the aim should be to leave as full a stand of hills as is obtainable from the initial stand being worked. Few roots of marketable size are likely to be produced in hills containing more than a maximum of 3 plants. Therefore, precision planting of high quality sheared seed on a clean and well prepared seed bed must be the foundation for the thin, uniform initial stand from which an approximately full stand of predominantly 1- and 2- plant hills can be saved by the appropriate machine operation.

CHART I. Comparative yields of sugar beet roots from full stands of hills with different spacings in 20 inch rows. Fort Collins, Colorado.

		Percent 60% 70% 80% 90% 100%
1938-39	20 x 10 singles	100.00
1938	20 x 20 doubles	95.98
1939	20 x 20 doubles; Com'cl.	88.41
1939	20 x 20 singles; "	88.46
1939	20 x 20 doubles; Hybrid.	83.60
1939	20 x 20 singles; "	89.53
1939	20 x 20 doubles; Inbred.	67.86
1939	20 x 20 singles; "	64.65
1939	20 x 14 singles;	100.00
1939	20 x 8 singles;	102.53
1939	20 x 20 singles;	98.87
1937-45	20 x 12 singles;	100.00
1937-38	20 x 8 singles;	95.55
1937-38	20 x 16 singles;	99.25
1937-39	20 x 8 singles;	97.89
1937-39	20 x 16 singles;	98.67
1945	20 x 12 (100 hills, 129 Pl.)	100.13
1945	20 x 10 (117 hills, 155 Pl.)	96.84

Percent 60% 70% 80% 90% 100%

CHART II. Comparative yields of sugar beet roots from reduced stands of hills. Fort Collins, Colorado. 1937-1945.

All tests		Hills 100	Plants 100	60% 70% 80% 90% 100% (100.00)
1937-39	Space-stand	70.7	70.7	96.13
1941-43	Space-stand	70.4	70.4	92.04
1944	Rate of seeding	67.6	80.6	91.04
1945	Rate of Seeding	73.8	130.7	90.96
1945	Population study	70.8	83.5	92.84
1945	Population study	69.8	89.9	88.90
1945	Population study	70.2	99.0	90.06
1937-39	Sp.-stand, 8"-40%	61.0	61.0	83.69
1945	Population study	60.1	77.4	85.48
1944	Rate of seeding	55.1	68.8	79.25
1941-43	Space-stand	50.8	50.8	80.30
1945	Rate of seeding	47.8	85.4	78.95
1945	Population study	50.6	65.1	78.97
1945	12" in 40" rows	(50)	50.9	78.05
1945	8" in 40" rows	(50)	77.7	74.94
1937-39	Space-stand	40.7	40.7	78.07
1945	Population study	41.1	52.8	76.77
1941-43	Space Stand	30.9	30.9	64.03
1937-39	Space Stand 16"-40%	31.0	31.0	70.51
1944	Rate of seed. Pellets	27.3	30.6	62.44
1944	Rate of seed. 1.16#	25.4	32.4	61.79

60% 70% 80% 90% 100%