

Crossing Experiments in Sugar Beet Lines

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Hybridization of inbred lines and of selections has been found to produce marked improvement in yielding ability in many crops. Stewart et al (3)² reported increased yields of hybrids over parent inbreds and check varieties in the sugar beet. A study of variety hybrids reported in 1942 (2) proved that increased yields were possible by crossing certain varieties. The present study was undertaken to determine what improvement might be obtained from the crossing of open-pollinated mother lines selected from a single variety.

Origin of Parent Lines

Root selections were made in 1939 from an elite stock of American No. 1 known as 8-406-0 (2). In 1940, 192 of the best of these roots were set out in a space-isolated group for seed production, and from this group some 50 plants were harvested separately as mother lines for field test in 1941. In 1940 another selection of roots was made from the same variety and in 1941, 177 roots were planted in an isolated group. From this 1941 group, 75 plants were harvested separately for mother line test in 1942. The root selections of 1940 and 1941 were made for leaf spot resistance in the field, and while the roots were in winter storage they were tested for sucrose and the largest beets with high sucrose-percentage were saved for the summer groups.

Nursery plot tests of the plant progenies were made in 1941 and 1942 and significant differences were obtained for resistance to leaf spot, for sucrose percentage, and for yield of beets and sugar per acre. Only the lines which appeared most promising were selected for greenhouse crossing work. In 1941 the lines selected were Nos. 8, 26, 35, 38, and 83. In 1942 root selections of the Nos. 26 and 35 were made from greenhouse-produced seed, and from the 1942 tests the lines No. 5, 25, 28, and 33 were selected.

Experimental Methods

Selected roots of the mother lines to be used for crossing experiments were taken from the field in late October of each year, 1941 and 1942, and stored in the root storage room for a period of 9 weeks. The beets were potted in 8-inch pots and transferred to the greenhouses on January 2 of each year, 1942 and 1943. Temperatures in the greenhouse were kept between 55° and 65° Fahrenheit until February 25, after which date the temperature was allowed to go above

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²Italic numbers in parentheses refer to literature cited.

70° Fahrenheit during the daytime. Supplemental light was given during the entire night period from January 10 to March 31. These conditions produced fairly uniform bolting, flowers began to shed pollen by February 15, and by March 10 practically all plants had flowered.

In the 1942 winter season 40 beets were used from each of the 5 lines selected, and all possible cross combinations of lines were made, as well as sibs of each line. The bag switching technique (2) was employed for this work. An average of 20 plants (both parents) were used for each cross and for each sibbing of parent. Number 8 Kraft grocery bags were used entirely. In 1943 an average of 50 beets from each of the 6 selected lines were used and all possible combinations of crosses made, as well as sibs of each of the 6 parent lines, using the same back switching technique as was employed the previous season.

Care was taken to ensure maximum crossing of the two parents. Each pair of plants selected for crossing had to be in the same stage of flower development, and if, after bagging, one plant failed to be a good pollen producer, a better plant was selected. Bags containing less than 50 seeds were discarded at harvest as an added precaution against possible self-pollination (2). Seed in all bags of each cross (or sib) was then bulked for use in field trials. The seed lots produced varied from 1,500 to 5,000 seed balls and were adequate to plant the tests planned. The check variety, American No. 1 (8-406-0), and Schreiber SS, a foreign variety susceptible to leaf spot, were included in the tests. These varieties were not produced in the greenhouse but came from large bulk lots of seed.

In both seasons, 1942 and 1943, the tests were planted on the Rocky Ford Experimental Station farm. The test fields used were inoculated with leaf spot and sprinkled by a Skinner sprinkling system to ensure a leaf spot epidemic.

All cultures were planted in five replications of single-row plots in 1942. Rows were 36 feet long, spaced 20 inches apart, with beets spaced 20 inches apart in the row. In the 1943 season the same size of plot was used and the same plant spacing, but it was possible to plant 10 replications of each culture. All beets from each plot in both tests were harvested for yield and sucrose percentage.

Experimental Results

There were 10 hybrids, 5 parent lines, and the 2 check varieties, or a total of 17 cultures in the 1942 test. In the 1943 test there were 15 hybrids, 6 parent lines, and 2 check varieties, for a total of 23 cultures. The results of the 1942 test are given in table 1.

Table 1.—Performance of open-pollinated mother lines, all possible hybrids, and check varieties, Rocky Ford, Colo., 1942.

Hybrid No.	Hybrid (a x b)	Parent a	Parent b	Hybrid a x b
Tons beets per acre				
1	8x26	15.33	15.41	18.73
2	8x35	15.33	15.89	17.47
3	8x38	15.33	11.62	17.84
4	8x83	15.33	15.17	14.48
5	26x35	15.41	15.89	20.41
6	26x38	15.41	11.62	16.58
7	26x83	15.41	15.17	18.43
8	35x38	15.89	11.62	18.55
9	35x83	15.89	15.17	18.66
10	38x83	11.62	15.17	18.58
Average.....		15.10	14.27	17.97
Variety parent of lines (8-406-0 Check).....				14.53
Foreign variety check.....				13.62
Significant difference (odds 19:1).....				3.64
Sucrose percentage				
1	8x26	15.84	15.18	14.94
2	8x35	15.84	14.44	13.94
3	8x38	15.84	15.14	15.72
4	8x83	15.84	14.34	15.82
5	26x35	15.18	14.44	14.64
6	26x38	15.18	15.14	14.78
7	26x83	15.1	8 14.34	15.10
8	35x38	14.44	15.14	14.92
9	35x83	14.44	14.34	14.68
10	38x83	15.14	14.34	15.40
Average.....		15.29	14.68	14.99
Variety parent of lines (8-406-0 Check).....				13.84
Foreign variety check.....				12.32
Significant difference (odds 19:1).....				1.01
Pounds sugar per acre				
1	8x26	4,860	4,671	5,602
2	8x35	4,860	4,583	4,893
3	8x38	4,860	3,508	5,605
4	8x83	4,860	4,360	4,586
5	26x35	4,671	4,583	5,967
6	26x38	4,671	3,508	4,908
7	26x83	4,671	4,360	5,555
8	35x38	4,583	3,508	5,569
9	35x83	4,583	4,360	5,470
10	38x83	3,508	4,360	5,644
Average.....		4,613	4,180	5,380
Variety parent of lines (S-406-0 Check).....				3,991
Foreign variety check.....				3,346
Significant difference (odds 19:1).....				1.113

Despite a high standard error due mainly to very small plots and lack of replication, significant differences were obtained between hybrids and between hybrids and parent lines. As an average the 10 hybrids were highest in yield of beets and of sugar, followed by the 5 parents, with the check varieties last in yield rank. The highest yielding hybrid, 26 x 35, was significantly higher than either of the parent lines or check varieties. This hybrid was slightly lower in

sucrose than the average of the 10 hybrids, but significantly lower than only two hybrids. The lowest yielding hybrid was 8 x 83, and although its yield of beets was lower than either parent, the difference was not at significant level. This hybrid was significantly higher in sucrose percentage than four hybrids.

Since the mother lines No. 26 and No. 35 were superior parents as judged not only as a single cross but from the average yield of all four of their possible hybrids, these lines were selected for use in 1043, together with the four lines selected from the 1942 mother line tests. The data from the 1943 test are given in table 2.

In this test the hybrids, as an average, were higher in beet and sugar yield than the parent, lines, and significant differences were obtained between hybrids, and between hybrids and their parent lines. Line No. 26 was significantly higher, and line No. 5 significantly lower in yielding ability than the parent variety 8-406-0. In sucrose percentage the foreign variety was significantly lower than all others except line No. 25 and hybrid 5 x 25. All sucrose percentages were lower than normal because of late planting, a severe leaf spot epidemic, and heavy rains prior to harvest.

In order to show clearly the effect of the crossing of the mother lines, a summary of all significant differences (at odds level of 19:1) was made from tables 1 and 2. This summary is given in table 3.

It is important to know whether parent mother lines producing high yields also produce high yielding crosses, since at the present time controlled crossing is not possible in commercial seed fields. Accordingly, correlation coefficients were calculated using the average yield of the two parents and the yield of the resulting hybrid. For the 25 hybrids the correlations were as follows:

$$\begin{array}{l}
 \text{A+B} \qquad \qquad (r = \pm 0.80 \pm 0.07 \text{ tons beets per acre.} \\
 \text{————— : A x B} = (r = \pm 0.90 \pm 0.04 \text{ sucrose percent.} \\
 \text{2} \qquad \qquad \qquad (r = \pm 0.89 \pm 0.04 \text{ pounds sugar per acre.}
 \end{array}$$

It is apparent that in these selections when the average yield of the parent lines was high the resulting hybrid in most cases was high in yield. This is not an uncommon observation in corn (1). However, it is observed that because the correlation is not perfect some poor yielding hybrids could be obtained from relatively good yielding parent lines. It is of utmost importance to eliminate such lines by determining their worth in cross combination before commercial seed is made. In table 1 Lines 8 and 83 are relatively high in beet yield, but the hybrid does not have the increased yield found in hybrids made

Table 2.—Performance of open-pollinated mother lines, all possible hybrids, and check varieties, Rocky Ford, Colo., 1943.

Hybrid No.	Hybrid (a x b)	Parent a	Parent b	Hybrid a x b
Tons beets per acre				
1	5x25	10.19	12.13	13.20
2	5x26	10.19	15.22	13.50
3	5x28	10.19	12.28	12.75
4	5x33	10.19	12.69	12.84
5	5x35	10.19	11.93	13.46
0	25x20	12.13	15.22	13.84
7	25x28	12.13	12.28	12.39
8	25x33	12.13	12.09	13.08
9	25x35	12.13	11.93	13.89
10	20x28	15.22	12.28	14.78
11	20x33	15.22	12.69	15.89
12	20x35	15.22	11.93	18.05
13	28x33	12.28	12.09	12.12
14	28x35	12.28	11.93	13.53
15	33x35	12.09	11.93	15.10
Average.....		12.10	12.00	13.90
Variety parent of lines (8-400-0 Check.).....			12.85	
Foreign variety check.....				12.41
Significant difference (odds 19:1).....				2.28
Sucrose percentage				
1	5x25	12.37	10.32	10.73
2	5x20	12.37	12.18	11.66
3	5x28	12.37	12.77	12.30
4	5x33	12.37	11.90	11.74
5	5x35	12.37	11.79	12.22
0	25x20	10.32	12.18	11.56
7	25x28	10.32	12.77	12.23
8	25x33	10.32	11.96	11.83
9	25x35	10.32	11.79	12.75
10	26x28	12.18	12.77	11.87
11	26x33	12.18	11.96	12.26
12	26x35	12.18	11.79	11.98
13	28x33	12.77	11.90	12.12
14	28x35	12.77	11.79	13.05
15	33x35	11.96	11.79	13.50
Average.....		11.81	11.99	12.12
Variety parent of lines (S-406-0 Check.).....				10.94
Foreign variety check.....				9.98
Significant difference (odds 19:1).....				9.4
Pounds sugar per acre				
1	5x25	2,548	2,508	2,850
2	5x20	2,548	3,728	3,138
3	5x28	2,548	3,155	3,160
4	5x33	2,548	3,077	3,055
5	5x35	2,548	2,819	3,306
6	25x20	2,508	3,728	3,207
7	25x28	2,508	3,155	3,084
8	25x33	2,508	3,077	3,113
9	25x35	2,508	2,819	3,576
10	26x28	3,728	3,155	3,587
11	26x33	3,728	3,077	3,941
12	26x35	3,728	2,819	4,354
13	28x33	3,155	3,077	2,979
14	28x35	3,155	2,819	3,588
15	35x35	3,306	2,819	4,079
Average.....		2,905	3,056	3,403
Variety parent of lines (8-400-0 Check.).....				2,809
Foreign variety check.....				2,523
Significant, difference (odds 19:1).....				630

Table 3.—Significant increase or decrease in productivity of 25 line hybrids as compared to parent lines, Rocky Ford, Colo., 1942-1943.

Number of hybrids	Tons beets per acre	Sucrose percentage	Sugar per acre
Lower than both parents	0	0	0
Lower than one parent	0	2	0
Higher than one parent	9	6	9
Higher than both parents	3	2	4
Showing no significant difference	13	15	12
Total hybrids tested*	25	25	25

*One hybrid 25x35 was included in both 1942 and 1943 tests.

from other lines. In mass selection these lines, being high in yield, would undoubtedly be included in the breeder's stock increase.

Discussion and Conclusions

The data obtained in this study indicate that: there was an appreciable amount of hybrid vigor in crosses of open-pollinated mother lines selected from the parent variety. In 1942 the average sugar per acre yield of the 5 parent lines was 4,1196 pounds as compared to 5,380 pounds for the average of the 10 possible hybrids; and in 1943, 6 parent lines produced an average sugar per acre yield of 2,980 pounds as compared to 3,403 pounds for the average of the 15 possible hybrids. Of the 25 hybrids tested, 9 were significantly higher in sugar per acre yields than one parent, 4 were significantly higher than both parents, and 12 showed no significant differences. Despite the average higher yield of hybrids over parent lines, sucrose percentage was not depressed.

Significant differences were obtained between the hybrids in both seasons for sugar per acre yield. The best yielding hybrid in the 1942 tests, 26 x 35, was highest in yield rank in 1943. In correlation tests it was found that high yielding parent lines usually gave high yielding crosses, but this relationship was not perfect.

The selected mother lines, as an average, produced a beet yield not significantly higher than the parent variety. All improvement obtained was in sucrose percentage and was due mainly to the selection of lines more resistant to leaf spot. The foreign check variety was not significantly different in beet yield from the parent variety but was significantly lower in sucrose percentage because of attacks of leaf spot to which this variety was highly susceptible.

From the results obtained in this study it is apparent that some improvement in sugar per acre yields would have been obtained from making bulk increases of the five lines selected in 1941, and the six lines selected in 1942. However, by making and testing all the hybrid

progenies, a selection of lines could be made, not only on their own yielding ability but also on their ability to produce maximum hybrid vigor effects, thereby making possible a still greater improvement in yield.

Literature Cited

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