COMPARISON OF SOME ADVANCED GENERATIONS OF A HYBRID STRAIN OF SUGAR BEET WITH THE ORIGINAL THIRD GENERATION SELECTION1/

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Introduction

Sugar-beet breeding investigations in United States have reached the point where inbred lines are becoming available for use in hybrid combinations. There has been considerable exploration of the possibilities of combining existing inbreds which in themselves may be more or less satisfactory for commercial use, in order to obtain superior varieties for general introduction. Large mass increases from seed mixtures of more promising inbreds have been made, notably in the recent Bureau introductions, U. S. 217 and U. S. 200 X 215. By pooling the seed of inbred strains and then carrying this mixture forward to seed production, an attempt has been made to utilize first-generation hybrid vigor, the experience being that a considerable amount of hybridization occurs in the seed field. Obviously, the progenies consist of selfs of the parental strain and the hybrid. As yet, certified hybrids have not been produced in quantity for direct use by sugar-beet growers, nor have the F_1 hybrids been carried to advanced generations for commercial use. The following data dealing with Hybrid Strain 520 and its selected and non-selected advanced generations are presented as having bearing on the question of what may be expected from advanced generations of sugar-beet hybrids.

Origin of the Hybrid Strain 520

In August, 1930, the American Crystal Sugar Company planted a field on their West Ranch farm at Rocky Ford, Colo., with seed of their sugar-type variety, Flat Foliage, for the production of stecklings to be siloed and replanted in the spring of 1931 for seed production. A few rows on one edge of this field were left in the ground in the fall and a small proportion of the beets in these rows was alive the next spring, having survived the winter. Forty of these stecklings showing the least frost injury were planted in the spring of 1931 with 10 red garden beets which had been kept in a pit over winter by a local gardener. These red beets are believed to have been of the Detroit Dark Red variety. The red beets were slow in starting but did produce a scanty growth of seed stalks, blooming rather late in the season. The following year, 1932, the open-pollinated seed saved from the 40 sugar-beet plants was planted and showed that there had been about 5 percent of intercrossing of the sugar beets with the red garden beets.

A seed crop was produced in 1933 from the sugar beet X red garden beet hybrids, crossing taking place *inter se*. In 1934, a considerable second-generation progeny was grown. No genetic analysis of this crop was attempted. However, the presence of red, white, and a few yellow roots, the great range in root shape from garden-beet to sugar-beet type, and a considerable range in sucrose percentages are sufficient evidences that segregation for different characters had occurred. Many of the white roots were of such large size and

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1/ Agronomic investigations at Fort Collins, Colo. are conducted in cooperation with the Colorado Agricultural Experiment Station. The early work with Hybrid Strain 520 was conducted at Rocky Ford, Colo. in cooperation with the American Crystal Sugar Company. (Cooperative assistance of the Great Western Sugar Company, and the Holly Sugar Corporation in conduct of field tests with strain 520 is hereby acknowledged.)

fair to good sucrose percentage that it was decided to select for the production of a white-rooted third generation. Since the roots with white epidermis and flesh color lack the dominant factor Y, elimination of red or yellow fleshed beets in future progenies is thus accomplished.
The basis of selection in size and sucrose percentage was roughly that of gross sugar per root. No roots of pronounced garden beet shape were retained, but most of the selected beets were shorter and thicker than the conventional sugar-beet type and the crowns of many of the beets retained were unusually small. One hundred and twenty pounds of cleaned seed were produced in 1935 from a group planting of about 560 of these selected roots. This seed had the planting number 520 and this selected third-generation of the hybrid has been known since as Hybrid Strain 520.

Hybrid Strain 520 has been extensively tested in the beet-growing areas of Colorado (with the exception of the western slope) and in some other states on the eastern slope of the Rocky Mountains in 1936, 1937, 1938, and 1939. In general, it has equalled or surpassed the better commercial varieties in acre-yield of roots in these tests. Sucrose percentages have almost invariably been below those of the majority of commercial varieties with which comparisons were made. However, the sucrose percentage of Hybrid Strain 520 has not been so low as to make the variety definitely unsatisfactory for sugar manufacture. Because of the high yield of roots, the acre-yield of sugar has, in general, been approximately equal to that of the better commercial varieties. Examples are the 1937-1939 averages at Fort Morgan, Colo., in a high-yield, low-sucrose-percentage area; and the 1938 test at Sheridan, Wyo., where relatively high percentages of sucrose are expected. Summarized data from these tests are given in Table 1.

The showing of Hybrid Strain 520 in 1936 and in succeeding trials appeared to justify further work with this hybrid. By the spring of 1939, several different advanced generations produced by direct increases, as well as by selection, were available for testing in comparison with the original stock. Those of most interest for the purposes of this report are as follows:

Table 1.--Results from comparative tests of Hybrid Strain 520 and a commercial variety at Fort Morgan, Colo. (3-year average), and at Sheridan, Wyo., in 1938.

Place	Variety	Acre-yield of		Sucrose
		Gross Sugar	Roots	
		pounds	tons	percent
Fort Morgan, Colo.	Hybrid Strain 520	5,593	21.57	12.93
do.	Commercial	5,590	19.68	14.10
Sheridan, Wyo.	Hybrid Strain 520	5,687	17.36	16.20
do.	Commercial	5,548	15.39	18.05

Planting designation	Current Breeding No.	Generation	Description
1	520	F_3	Foundation stock arising from Sugar Beet X Red Garden Beet
2	304	F_4	Selection from 520 on basis of saccharimeter test
3	301	F_4	Direct increase without selection from 520
4	302	F_5	Direct increase without selection from 304
5	300	F_4	Selection essentially the same as 304
6	250B	F_4	Selection from 520, for improved sucrose percentage; size of root ignored.
7	80186	F_4	Selection from 520 made in Wyoming (pink bud color)
8	80187	F_4	Selection from 520 made in Wyoming (green bud color)
9	250A	F_1	Hybrid of 520 X commercial
10	-	-	An American variety used as check
11	-	-	A European brand used as check

The strains listed above were used in trials in 1939 as follows: (1) all were included in a test on the College Farm at Fort Collins, Colo.; (2) five were used in strip plantings made in a farmer's field near Fort Morgan, Colo.; (3) six were used in a replicated test at Rocky Ford, Colo.; (4) six were used in a replicated test at Sheridan, Wyo.; and (5) one was tested at Sydney, Mont. An American variety used as a check was common to tests 1, 2, 3, and 4. A European brand used as a check was common to tests 4 and 5. Limited seed supply of certain of the strains and other considerations prevented uniform testing of all the above generations at each of the locations. The data as obtained at these five locations have been brought together in Table 2 for acre-yields of roots and gross sugar and for sucrose percentages.

Table 2.—Results obtained in 1939 at various locations with Hybrid Strain 520 and certain advanced generations. (Results given as averages.)

Planting designation	Variety	(1) Fort Collins Colo.	(2) Fort Morgan Colo.	(3) Rocky Ford Colo.	(4) Sheridan Wyo.	(5) Sydney Mont.	Averages Locations 1-3	Averages Locations 1-4
		tons	tons	tons	tons	tons	tons	tons
		Calculated Acre-Yields of Roots						
1	520	14.45	23.12	12.86	11.88	—	16.81	15.88
2	304	14.64	22.75	12.05	12.10	21.39	16.48	15.38
3	301	12.61	22.08	12.96	—	—	15.88	—
4	302	13.60	21.31	12.56	10.83	—	15.82	14.58
5	300	13.98	22.55	11.87	—	—	16.13	—
6	250B	13.47	—	—	—	—	—	—
7	80186	13.86	—	—	13.61	—	—	—
8	80187	13.34	—	—	12.52	—	—	—
9	250A	15.32	—	12.44	13.06	—	—	—
10	Check	13.74	20.54	11.05	10.19	—	15.11	13.88
11	Check	—	—	—	10.52	19.18	—	—
Difference required for significance 19:1		1.87	1.27	2.56	1.49	2.58		

Table 2 (con'td.)

Planting designation	Variety	(1) Fort Collins Colo.	(2) Fort Morgan Colo.	(3) Rocky Ford Colo.	(4) Sheridan Wyo.	(5) Sydney Mont.	Averages Locations 1-3	Averages Locations 1-4
		Sucrose Percentages						
		percent	percent	percent	percent	percent	percent	percent
1	520	15.96	15.20	16.73	14.60	—	15.96	15.62
2	304	16.27	15.41	17.06	15.15	15.54	16.28	15.97
3	301	15.61	14.82	16.59	—	—	15.67	—
4	302	15.85	15.07	17.00	14.68	—	15.97	15.65
5	300	16.05	15.44	16.98	—	—	16.16	—
6	250B	16.64	—	—	—	—	—	—
7	80186	15.29	—	—	14.71	—	—	—
8	80187	15.28	—	—	14.41	—	—	—
9	250A	16.39	—	17.23	15.19	—	—	—
10	Check	16.95	16.21	18.14	15.59	—	17.10	16.72
11	Check	—	—	—	16.24	17.17	—	—
Difference required for significance 19:1		.57	.49	.38	.54	.65		
		Calculated Acre-Yield of Gross Sugar						
		pounds	pounds	pounds	pounds	pounds	pounds	pounds
1	520	4,614	6,999	4,280	3,461	—	5,298	4,838
2	304	4,792	7,011	4,054	3,672	6,642	5,286	4,882
3	301	3,960	6,525	4,293	—	—	4,926	—
4	302	4,308	6,424	4,237	3,156	—	4,990	4,531
5	300	4,490	6,957	4,002	—	—	5,150	—
6	250B	4,490	—	—	—	—	—	—
7	80186	4,256	—	—	4,018	—	—	—
8	80187	4,084	—	—	3,612	—	—	—
9	250A	5,037	—	4,244	3,965	—	—	—
10	Check	4,663	6,742	3,974	3,169	—	5,126	4,637
11	Check	—	—	—	3,431	6,617	—	—
Difference required for significance 19:1		693	690	831	517	911		

Stands or soil variability, or both, were unfavorable in the case of the tests at Fort Collins, and Rocky Ford, Colo., and at Sheridan, Wyo., but it is believed that, in general, the reliability of the tests was not seriously impaired. However, in some cases, rather large differences do not reach the level of statistical significance.

It was hoped that these tests would give information on the relative progress to be expected from continued selection, chiefly for improved quality, following the original selection of desirable segregates from a hybrid.

The performance of 304, 300, 250B, 80186, and 80187 in relation to each other and in comparison with 520 should bear on this point. Since 520 was high in yield of roots and somewhat low in sucrose percentage, the purpose of further selection was to retain the high tonnage and increase the sucrose percentage of this hybrid, if possible. Seed of 304 was available for testing in 1938 and it, with 520, was included in plantings at Fort Collins, Colo., Fort Morgan, Colo., and Sheridan, Wyo. Data from these tests are summarized in Table 3.

Table 3.--Summary of performance of 304 and of 520 at three locations, Fort Collins and Fort Morgan, Colo., and Sheridan, Wyo., in 1938.

Variety	Acre-yield of gross sugar			Acre-yield of roots			Sucrose percentage		
	Fort Collins	Fort Morgan	Sheridan	Fort Collins	Fort Morgan	Sheri-dan	Fort Collins	Fort Morgan	Sheri-dan
	pounds	pounds	pounds	tons	tons	tons	percent	percent	percent
520	4,837	4,388	5,687	17.97	18.37	17.36	13.46	11.97	16.30
304	5,040	4,433	5,904	18.21	17.99	17.60	13.84	12.32	16.83
Commercial ck.	4,934	4,840	5,548	16.98	17.98	15.39	14.64	13.46	18.05
Difference required for significance 19:1	392	245	516	1.26	.86	1.41	.37	.34	.64

It appears from the 1938 tests that reselection has not sacrificed tonnage and that sucrose percentage has probably been increased significantly. When the data from the various 1939 tests are considered, it is found that 304 again exceeds 520 in sucrose percentage in every case, the differences reaching the level of statistical significance in some of the cases. Also, tonnage in the case of 304 has been quite satisfactorily retained. On the basis of the Fort Collins test, the selection for higher sucrose, 250B, shows a substantial increase in sucrose percentage. However, this increase in quality has been accompanied by a reduction of approximately one ton in acre-yield of roots. While this difference does not reach twice the standard error of a difference, it is too large to be entirely ignored as evidence of a trend. In these tests, 300 does not appear to be quite the equal of the first reselection, 304. However, the differences are not significant and the trend indicates that in this selection quality has been slightly raised without serious sacrifice of yielding capacity. The performance of the Wyoming selections 80186 and 80187 at Fort Collins, Colo., and at Sheridan, Wyo., in comparison with 520 and 304 is of interest in that the possibility of regional adaptation is involved since these selections were made from Wyoming-grown roots of 520. At Fort Collins, the Wyoming selections appear to be definitely lower in sucrose percentage than the original selection and both of the Colorado F_4's, 304 and 300. Yield of roots is also lower, but the differences are probably not significant on the basis of this test. 80186 exceeded 80187 in acre-yield of roots, sucrose percentage, and acre-yield of gross sugar at Fort Collins, Colo., but the differences do not appear to be significant. At Sheridan, Wyo., the Wyoming selections exceed 520 and 304 in root yield. In the case of 80186, these differences reach the level of statistical significance. The Wyoming selections do not differ significantly in sucrose percentage from 520. On the basis of this test, the selection of Wyoming-grown roots has resulted in a possibly significant increase in root yield without a loss in sucrose percentage. While the evidence is far from conclusive, it is possible that regional adaptation is indicated in this case. At Fort Collins and Rocky Ford, Colo., and at Sheridan, Wyo., 250A, the 520 X Commercial hybrid gave a high yield of roots with a sucrose percentage that is probably significantly higher than the sucrose percentage of 520 in all cases. These tests indicate that crossing of such a strain as 520 with a good commercial variety promises as quick or quicker improvement than continued selection.

A question which arises in beet breeding work may also be considered, namely, can the general trend of performance of a hybrid sugar beet best be maintained when non-selected increases are made for production of seed in com-

mercial quantities. The relative performance of the unselected advanced generations, 301 and 302, should be indicative of the performance of commercial increases of the Hybrid Strain 520. While the groups of stecklings which produced these seed lots consisted of only a few hundred roots, they are probably comparable to a crop of seed produced on a commercial scale by direct increase of seed since there was no selection of the roots used for these groups. In general, the differences in acre-yields of roots and acre-yields of gross sugar shown by the various strains of 520, whether selected or unselected, did not in these tests reach the level of statistical significance. This is true of the unselected strains, 301 and 302, whether they are compared with 520, the selected strains, or with each other. In the Rocky Ford test, the extreme difference is less than 300 pounds of sugar per acre. In the other three tests, in which one or both of the unselected strains were included, there appears to be a definite trend toward slightly lower yields of roots in comparison with the parent strains, 520 and 304. The trend in sucrose percentages is the same; 301 is slightly lower than 520, and 302 slightly lower than 304. These differences both in yield and quality are small and, on the basis of these tests, the unselected increases are not definitely poorer than the parent strains. It is believed that the basis of selection of both 520 and 304 was such as to retain a high degree of heterozygosity for the factors influencing both yield and quality. If this is true, it is logical to expect that the normal segregation in the unselected increase of either would result in certain individuals with small size or low sucrose percentage. If this has occurred, there might be a lowering of the general level of performance. This does not necessarily follow, however, since in the case of sucrose percentage, at least, there should also be segregation in the direction of higher sugars. It is worthy of note that 302 appears to have retained a portion of the improvement in sucrose percentage gained in the selection of 304. These tests, while not proving the case, at least can be interpreted as not disproving the practicability of increasing a hybrid such as 520 without selection after the third and fourth generations.

Summary and Conclusions

A high-yielding hybrid sugar beet has been produced from the cross of sugar beets from a variety classifiable as of sugar type and red garden beets.

An increase in quality, as measured by sucrose percentage, was obtained by reselection from the third generation. This increase in quality was not accompanied by a material decrease in tonnage.

When the selected fourth generation was advanced to the fifth generation without selection, part of the increase in sucrose percentage was retained. The unselected fourth and fifth generations, on the basis of these tests, were probably not significantly lower in sucrose percentage and root yield than the parent third and fourth generations, respectively.

The slightly higher tonnage and increased sucrose percentage shown by the cross of 520 roots with a good commercial variety in comparison with 520 shows that this method of utilizing a promising hybrid combination should not be overlooked.

It appears from these tests that it is possible by careful reselection to increase the quality of a hybrid strain without materially reducing the yield of roots.

Since in these tests definite retrogression in yielding capacity and quality of a hybrid strain was not found as advanced generations beyond F_3 were made, it may be possible to make direct increases from similar hybrid stocks without material loss occurring in yielding capacity as measured in acre-yield of gross sugar.