A Study of Varietal Adaptation with Sugar Beets—1937 to 1941, Inclusive

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Breeding of sugar beets to increase the sugar-per-acre yield is as old as 1 lie beet-sugar industry itself. The winning of this sugar plant from the common stocks of beets used chiefly as feed for animals is a demonstration of man's success through a century and a half of endeavor in adapting a plant to highly specialized use. The need for breeding work was recognized in .1809 by Achard, who clearly sensed the future of the industry as hinging on securing suitable varieties, and that these could come only as a result of breeding work.- Koppy laid the foundation for this improvement work with the development of the White Silesian beet, which is reputed to be the "mother stock of all the sugar beets in the world." After the introduction and use of the polariscope for analysis of the beet juice as an aid in the selection of mother beets, rapid improvement in the quality of the sugar beet resulted. The increase in knowledge of breeding principles, combined with further precision in analysis technique has made possible continued improvement in the quality and yield of this crop.

Up to comparatively recent years, most of the beet-breeding work was done by certain of the larger beet-seed producing companies of Europe. In order to meet a wide range of soil and climatic conditions, the European producers endeavored to sort out hereditary combinations in the sugar beet, so as to conform to three general types, namely: Sugar-, intermediate, and tonnage types. From variety testing work done in this country over a period of 4 years it was found that in general these types, or "brands," performed essentially according to type designation.'[3] Breeding work in America has, however, become a necessity because of diseases to which foreign varieties are susceptible, and against which diseases, plant resistance can be obtained. Furthermore, varieties of sugar beets have been found to differ in their productive abilities in different areas, even where diseases normally are not a factor. Such differential growth response, if generally found, can be extremely important in the production of maximum .yields of sugar in the beet-growing areas.

In the areas served by the American Crystal Sugar Company, a wide range of growing conditions exists. Beets are grown at Ox-

'Manager, Plant bree'der, and Field Assistants, respectively; Beet Seed Operalions. American Crystal sugar Company.

[2]Coons, G. H. Improvement of the Sugar Beet. U. S. D. A. Yearbook. 1936; pp 625-626.

[3]Skuderna, A. W. et al. Evaluation of Sugar Beet Types in Certain Sugar Beet growing- Districts in the United States. U. S. D. A. Cir. 476. 1938.

nard in southern California, in a latitude of 35° with a coastal climate, and at East Grand Forks in northwestern Minnesota in a latitude of 48° with a dry continental climate. In the San Luis Valley of Colorado, beets are grown at an altitude in excess of **7,600** feet and in the Sacramento Valley in California at approximately sea level. Soil conditions range from peat land to those of low-humus and low-**nitrogen** content. With such diversity of crop conditions existing, the plant breeder must immediately conclude that, disease conditions excluded, the chances of any one variety being the best yielder in all areas, are very remote.

In this paper dealing with varietal adaptability, the results of variety tests to be presented were obtained in American Crystal Sugar Company areas, during the 5-year period 1937 to 1941, inclusive.

Experimental Results

In 1937, three varieties of sugar beets, one of European origin and the other two domestic, were tested under widely different conditions of length of growing season, altitude, and moisture. In California, the test was conducted at practically sea-level elevation, under pump irrigation, and extended over an 8-month period. In Colorado, the beets were grown at an altitude of 4,200 feet, and under irrigation, the length of the growing season being 6 months. In Minnesota, the elevation was about 860 feet, and length of growing season about $4^1/_2$ months. The results are shown in table 1.

Table 1.—Sugar-per-acre yield of 3 varieties of sugar beets tested in 3 localities—1937.

(Expressed in percentage of the best in each test)

Variety \ Location:	California Oxnard	Colorado Rocky Ford	Minnesota East Grand Forks
R & *G* Normal	100.0	76.0	92.0
U. S. No. 217	80.0	98.0	85.0
American No. 3	85.0	87.0	100.0
Sig. diff. in percentage	14.2	6.3	7.7

The conclusions from this test were to the effect that a different variety was the best producer at each location. Also, it was apparent from these results that an extensive breeding problem exists in the production of adapted varieties for these conditions.

In 1938, these comparative tests were continued with 4 locations included in the study. The results are shown in table 2.

Table 2.—Sugar-per-acre yield of 4 varieties in 4 locations—1938.
(Expressed in percentage of the best in each test)

Variety	Location: California Oxnard	Colorado Rocky Ford	Iowa Mason City	Minnesota East Grand Forks
R& G Normal	100.0	82.7	82.2	80.2
American No. 3	79.0	85.4	74.2	100.0
TJ. S. No. 14	83.0	80.6	73.5	07.8
American No. 30		100.0	98.2	89.4
Sig. diff. in percentage	17.0	10.8	0.6	0.1

From the above data, it is observed that in all 4 areas, there are statistically significant differences between the highest and lowest-producing varieties, and, as in 1937, there was a complete reversal in rank of the R and G Normal and American No. 3 varieties, in the Oxnard and East Grand Forks areas. From these tests, it appeared that the American No. *SO* variety could be used with equal facility both in the Rocky Ford and Mason City areas.

In 1939, a group of 14 varieties were tested in 11 locations. The results obtained are shown in table 3, which gives percentage yields in pounds sugar per acre for 4 of the varieties grown at the same locations as in the 1938 test.

Table 3.—Sugar-per-acre yield of 4 varieties in 4 locations—1939.
(Expressed in percentage of best yieltler of each test)

Variety	Location: California Oxnard	Colorado Rocky Ford	Iowa Mason City	Minnesota Kast Grand Forks
Schreiber S. S.	98.8	84.8	80.3	88.6
American No. 3	90.4	91.6		100.0
U. S. 200 x 215	80.2	89.6	88.7	83.3
American No. 36	81.4	100.0	98.6	88.9
Sig. diff. in percentage	13.8	8.5	5.5	10.2

In this set of results, the Schreiber variety ranked near the top in the Oxnard test. American No. 3 was again the high-yielding variety at East Grand Forks. Leafspot incidence was such as to affect the sugar-per-acre yield of the TJ. S. 200 x 215 variety in the Rocky Ford and Mason City tests. The American No. 36 variety again proved to be an acceptable variety for these two areas.

From the results of these 3 years, it is apparent that varieties did perform differently in different areas. Therefore, in order to reduce as far as possible the testing of selections which from their origin were known to be wholly or in part unsuited to certain areas, 4 general breeding areas were established. These are as follows:

No. 1—Rocky Ford, Colorado, and Grand Island, Nebraska.

No. 2—Oxnard, San Joaquin Valley, Clarksburg, California.

No. 3—Alamosa, Colorado; Missoula, Montana • and East Grand Forks, Minnesota.

No. 4—**Chaska,** Minnesota, and Mason City, Iowa.

In establishing these breeding areas, it was thought that there was greater likelihood of a variety being a satisfactory performer in the factory districts of each area, than between different areas. It was expected, however, that within each area differential response of varieties might be observed.

In 1940, an interesting yield comparison was obtained from two mass selections of the Schreiber S. S. variety, both tested for yield performance along with the unselected parent, at all three factory areas of breeding area No. 3. The selection 8-801 was made at East Grand Forks, Minnesota, and the selection 0-301 was made at Missoula, Montana. In table 4 the data obtained on this test are given.

Table 4.—Sugar-per-acre yields of 2 selections of Schreiber S. S., and the parent, in 3 factory areas—1940.
(Data expressed in percentage of the highest yielder in each test)

Location:	Colorado Alamosa	Montana Missoula	Minnesota East Grand Forks
8-801	100.0	88.9	100.0
0 301	84.3	100.0	87.3
Schreiber (Parent)	84.1	82.9	85.5
Sig. diff. in percentage	8.0	10.1	9.5

At Alamosa, Colorado, the selection of 8-801 outyielded 0-301 and the Schreiber parent. At Missoula, the local selection 0-301 was higher in yield than the East Grand Forks selection and the parent. At East Grand Forks, the local selection 8-801 was higher in yield than the Missoula selection and the parent. It is also interesting to observe, from the data on tons-beets-per-acre yield and percentage sucrose, from which the above percentage table on sugar-per-acre yield was computed, that each selection in its own locality exceeded in tons yield and was equal to or better than the parent variety. When the more simple methods of selection are productive of such striking differences in adaptability of a variety, it can be confidently expected that future varieties are likely to show still greater differences as more precise breeding methods are employed.

In 1941, the reactivity of 17 varieties was compared in the non-curly-top areas as represented by breeding areas 1, 3, and 4. Rocky Ford, Colorado, was selected as representative of area No. 1, and Ohaska, Minnesota, as representative of area No. 4. Because of the wide difference between localities represented in breeding area No. 3, and the large acreage of sugar beets Involved, both Missoula, Montana, and East Grand Forks, Minnesota, were included. In table 5 are shown the results of tons beets, sucrose percentage, and pounds sugar per acre of those varieties which were significantly higher yielding In the test.

Table 5.—Yields of 7 varieties compared at 4 locations for tons beets, percentage sucrose, and pounds sugar per acre—1941.

Location:	Montana Missoula	Colorado Rocky Ford	Minnesota Chaska	Minnesota East Grand Forks	Average of 4 locations
		Tons beets per acre			
0-601	15.92	13.64	17.34	17.40	16.075
200 x 215 x 216	17.69	13.57	17.48	15.83	16.143
0-705	16.38	13.56	17.12	16.30	15.840
0-401	15.53	12.36	16.40	15.80	15.022
Schreiber S. S.	16.51	13.12	14.36	16.18	15.043
0-402	16.29	12.96	16.53	15.64	15.110
Amer. No. 1 Com'l.	15.52	12.60	15.17	15.82	14.702
Sig. diff. (19:1)	1.60	1.41	1.52	1.10	.780
		Percentage of sucrose			
0-601	17.21	14.13	12.93	14.26	14.633
200 x 215 x 216	16.93	13.09	12.36	14.34	14.330
0 705	16.88	13.38	12.01	14.61	14.220
0-401	17.23	14.29	12.99	14.80	14.828
Schreiber S. S.	17.21	13.04	12.73	14.51	14.373
0-402	17.11	13.63	12.19	14.50	14.356
Amer. No. 1 Com'l.	17.00	14.26	12.45	14.64	14.618
Sig. diff. (19:1)	.37	.58	.74	.93	.846
		Pounds sugar per acre			
0-601	5479	3835	4456	4071	4685
200 x 215 x 216	5902	3716	4319	4533	4640
0 705	5530	3612	4123	4766	4573
0-401	5347	3527	4253	4674	4450
Schreiber S. S.	5688	3386	3674	4704	4362
0-402	5566	3423	3772	4546	4327
Amer. No. 1 Com'l.	5282	3508	3772	4639	4323
Sig. diff. (19:1)	549	359	499	412	233.2

Since these tests were statistically analyzed as a 17 variety, 8 bloc, 4 location test, the data of analysis are of interest. These data are presented in table 6.

From the data presented in tables 5 and 6, some interesting information is developed. The statistical analysis shown in table 6 indicates highly significant differences for areas, blocks, varieties, and interaction of varieties x areas, for tons beets, percentage sucrose, and pounds sugar-per-acre yield. Comparing the mean squares for varieties with the mean squares for the interaction varieties x areas, it is apparent that although the varieties were significantly different in yield for the entire test, certain varieties showed a significant differential response in different areas. It is also indicated from the large mean square value for varieties compared with the interaction varieties x areas, that some varieties performed well in the 4 areas. This is factually brought out by a study of the results shown in table 5.

Table 6.—Analysis of variance of 17 varieties in 4 areas—1941.

Variation due to:	D. F.	Mean squares	F value	Significance beyond:
		Tons beets per acre		
Areas	3	290.2657	119.17	1-percent point
Blocks	7	8.5021	3.41	1-percent point
Varieties	16	10.4698	4.30	1-percent point
Varieties x areas	48	4.2805	1.72	1-percent point
Error	469	2.4357		
Total	543	4.4943		
		Percentage of sucrose		
Areas	3	523.8501	1190.84	1-percent point
Blocks	7	2.8920	6.02	1-percent point
Varieties	16	2.6864	5.59	1-percent point
Varieties x areas	48	1.0698	2.21	1-percent point
Error	469	.4802		
Total	543	3.5701		
		Pounds sugar per acre		
Areas	3	96,658,837	444.26	1-percent point
Blocks	7	620,657	2.85	1-percent point
Varieties	16	983,272	4.52	1-percent point
Varieties x areas	48	433,389	1.99	1-percent point
Error	469	217,569		
Total	543	797,226		

Tons Beets per Acre.—In these results, using 1.561 tons as the difference required for the variety comparisons at all locations, varieties 0-601, 200 x 215 x 216, and Schreiber S. S. were significantly high yielding in one or more areas. Variety 0-705, while of better than average yield in all locations, showed no significant yield differences between areas, although some were suggestively large. The sugar variety 0-401, and the American No. 1 Commercial variety produced acceptable yields of beets in all 4 locations. For the individual locations, varieties 0-601, and 200 x 215 x 216 were significantly high yielding in 3 of the 4 locations, with variety 0-705 a close second. While the 7 varieties shown were the highest yielding in the 17-variety test, it is apparent from a study of the average tonnage-yield result that varieties 0-601, 200 x 215 x 216, and 0-705 were the highest yielding of all varieties.

Percentage of Sucrose.—All of the varieties with the exception of 0-601 and 200 x 215 x 216 showed significant differences between locations in percentage of sucrose in the beet. Sugar varieties 0-401 and American No. 1 Commercial performed essentially according to designation, being outstandingly high at Rocky Ford, under condition of severe leafspot incidence which depressed sucrose values in the susceptible variety Schreiber S. S. The 0-401 variety also performed well at the other 3 locations, and in 2 of which the differences

in its favor were suggestively large. Of especial interest is the behavior of the 0-601 variety, which under the conditions of this test showed remarkably high-sucrose values when its heavy tonnage-yield performance is considered. While the differences in percentage of sucrose between locations were not significant, they were suggestively large in 2 locations and above average in the third location. The 200 x 215 x 216 variety performed uniformly well, everything considered. Comparing the varietal performance in the light of the average results, varieties 0-401, 0-601, and American No. 1 Commercial were the best in the test in percentage of sucrose.

Pounds Sugar per Acre.—In yield of pounds sugar per acre, varieties 0-601 and 200 x 215 x 216 excelled in all locations but one. Variety 0-705 was a consistently good producer of sugar in all locations, iu 2 of which the differences were suggestively large. The sugar variety 0-401 was also a good performer in 3 of the 4 locations, and represents a marked improvement over the parent variety American No. 1, from which it was reselectcd. The Schreiber S. S. variety showed marked reaction to leafspot susceptibility, being of low commercial value under conditions of moderate-to-severe leafspot incidence. Based on the performance as represented by the average results of all locations, varieties 0-601 and 200 x 215 x 216 were significantly higher yielding than the Schreiber S. S., 0-402. and American No. 1 Commercial varieties. Of these 2 varieties, 0-601 is apparently more desirable because of its high-sucrose value and therefore of higher manufacturing worth.

The results of this test follow in general the same pattern as of preceding years. There is, however, one exception which runs counter to the previous trend of results. Variety 0-601. a synthetic increase of selections made from 4 leafspot-resistant varieties at Mason City, Iowa, in 1940, was high yielding in tons beets and pounds sugar in 3 of the 4 locations. In percentage of sucrose, it was among the best. On the basis of these results, this synthetic variety comes more closely to fulfilling the requirements of a general variety for the locations included in this test than any variety tested thus far in these areas. This apparently indicates that varieties of a wide genetic base, resistant to leafspot and of good tonnage yield might- be used interchangeably for locations similar to these, and especially under conditions where seed of improved locally adapted varieties is not available.

Discussion and Conclusions

From comparative tests conducted over the 5-year period, 1937 to 1941, inclusive, it was observed that a number of commercial varieties performed by areas differently in tonnage yield of beets, and percentage of sucrose in the beet. It is evident that the highly varying environmental conditions of disease, soil type, altitude, latitude,

length of growing season, climate, and other factors affect the productivity of varieties differently. Although resistance to disease has been commonly observed to be a major factor in determining yields in certain areas, it was by no means the only factor of importance in these tests. This is clearly demonstrated in table 4, in which beet yields of leafspot-susceptible varieties tested under leafspot-free conditions, but varying as to other factors, are shown, and significant differences in yield were obtained.

Tn the 1941 tests (table 5) certain domestic varieties were found to be significantly high in yield in several of the areas under test. Varieties 0-601, and 200 x 215 x 216 appeared more nearly to meet the requirements of general varieties for interchangeable use in the 4 areas herein discussed. In the intermediate-yielding group, varieties 0-705 and to a lesser extent 0-401 were consistent performers regardless of area. On the other hand, the European variety Schreiber S. S, was lowest in yield in 2 areas because of high degree of susceptibility to the leafspot disease.

Tn view of the results obtained during this 5-year period of test, it appears highly necessary to test thoroughly new varieties in all areas where possible commercial utilization is planned. The results also indicate that as a general practice, it is desirable that commercial varieties used in any commercial sugar-beet growing area be made from increases of elite stocks originally selected in that area.

Report on 1941 Tests of U. S. 200 x 215, U. S. 215 x 216, and Other Varieties Arising in Leafspot-Resistance Breeding Investigations of the U. S. Department of Agriculture

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Agronomic evaluation tests were conducted in 1941 on U.S. 200 X 215 and allied varieties of sugar beet arising in the leafspot-resistance breeding project. Tests were conducted by members of the staff of the Division of Sugar Plant Investigations in cooperation with ex-

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