A Quarter Century of Progress in Sugar Beet Improvement by the Great Western Sugar Company

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Breeding work has been conducted by the Great Western Sugar Company since 1910. Previous reports have been made to this Society[2] of various phases of this work, and the general progress for the period 1922 to 1938 was evaluated in terms of breeding methods in the 1938 Proceedings pages 42-50.

Some very encouraging developments in new varieties which combine a high degree of resistance to leafspot *(Cercospora beticola)* with superior performance for both tonnage and sugar content seem to be of sufficient interest to justify a further report at this time.

In this connection, some attention will be focused on breeding methods. We do not intend to survey the method being used by various breeders except to observe that most of the commercial seed currently being used in this country is from varieties which have arisen either by mass selection or by some phase of progeny-test selection, in some cases with partial control of pollination by isolation methods. In our own work the progeny-test method has been used more or less consistently for most of the varieties of commercial value developed up to the present time. In recent years, however, several new unrelated sources of material have been introduced into the breeding program and it appears probable that some new genes for possibly both root production and sugar content have been acquired in this manner.

This report of progress will be confined to the improvement work conducted principally for the areas subject to attacks of the leafspot disease common in much of the area east of the Rocky Mountains.

Progress Since 1922

An attempt has been made to present graphically (Figure 1) the trend in "total sugar" content for the varieties of potential commercial value for the period 1922 to 1937 (each point on the curve for that period being a three-year mean) and the principal improvements in the form of commercial variety releases since that time. The curve for 1922-1937 was presented in 1938 and its significance discussed. The breeding program during that period resulted in a potentially new commercial variety each year, each such variety being tested against a standard to prove its comparative worth. The drop in total sugar indicated for the first two years after 1923 was considered to be the result of undue emphasis on sugar content. This being corrected in 1925, the curve showed a consistent rise for a few years, sloping off after 1930 or 1931 for no apparent gain for the next few years.

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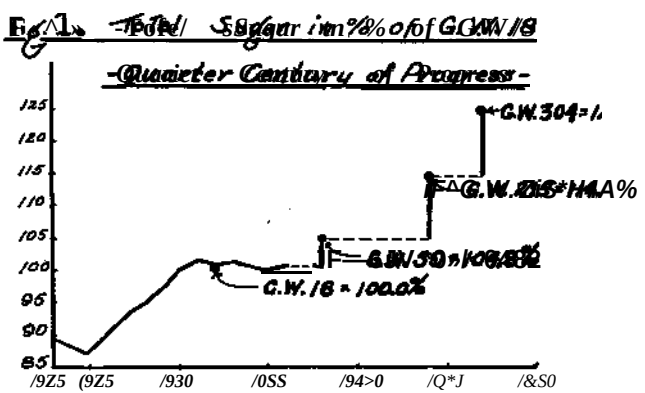
[2] Proc. Amer. Soc. Sug. Beet Tech., pp. 42-50, 76-9, 1938; 143-4, 147-8, 169-80, 1940; 322-5, 342-8, 1942; 259-262, 1946; 162-5, 175-8, 1948; 56-9, 1949 (Eastern Sec.).

In evaluating the results for these years it was pointed out that this pattern was similar to what corn breeders experienced in applying the ear-to-row method for adaptation of a corn variety to a new area. It was further concluded that except for possible improvements in yield through increased resistance to leafspot, there was not much to be hoped for by continuing the program without material change.



This conclusion, however, proved to be subject to the error of any long-time prediction, for *in* 1939 a variety which later became known as GW59 showed unusual promise in variety tests in which it was included for the first time. Curiously enough, a possible 25 to 50 percent of the inheritance of this variety traces back to one root, the remainder to a broad base of old family material. GW59 proved to be more tolerant to leaf-spot than the preceding commercial GW18, which character has no doubt had some influence in its performance record of 4.8 percent (see Figure 1) increase in total sugar over GW18 as an average of forty-two tests conducted over a period of 8 years.

Correlation Between Yield of Roots and Leafspot

In a study conducted in 1940, using a wide series of families planted with three replications at each of two locations, yield at Longmont, where leafspot did not develop, was correlated with leafspot estimates at Fort Morgan, where leafspot readings indicated a moderately severe epidemic. An *r* value of —.0516 was obtained, which was far from significant. From this it was concluded that a breeder could safely confine his efforts, so far as yield was concerned, to strictly LSR material. The direct effect of leaf-spot on yield and sugar content was well known. However, regression values for yield and percent sugar on leafspot, as determined from breeding

strain data, will serve to point up this relationship. These are given in percent of the standard variety (GW18) as follows:

Year	Location	Wt. of Roots	Percent Sugar	Total Sugar
1937	Longmont	3.62	0.80	Approx. 4.42
1938	Ft. Morgan	4.22	1.33	Approx. 5.55
1940	Ft. Morgan	1.72	0.39	Approx. 2.31

Leafspot developed later in 1940, hence its effect was less severe than in 1937 or 1938. The indicated loss in total sugar of from 2.31 percent to 5.55 percent for each unit of increase in leafspot estimate on the scale of 1 = none to 10 = complete necrosis shows how very important this disease can be as a limiting factor in production.

Recent Developments

Since the leafspot disease potentially is a limiting factor for much of the beet-growing area east of the Rockies, this character was sought for in most of the breeding strains studied. Breeding strain tests were conducted on an extensive scale. Major emphasis was placed on yield, sugar content, and leafspot resistance in the selection program. As many as 10,000 plots per year were necessary for a few years to carry all phases of the selection and testing program, not including seed production. Many new sources of potentially valuable material, among which were hybrids with *Beta maritima*, were included in the selection material. Many lots which possessed some resistance to leafspot along with some very undesirable qualities were taken through a careful screening plus a thorough polishing process. A synthesizing program followed, in which numerous possible combinations of strains from these various sources were brought back together, these re-combinations being then entered into variety tests at several locations in the four-state area served by this company.

Two of the more recent developments, GW215 and C304, have been quite thoroughly tested for three years in a total of twenty replicated variety tests, these results being shown in Figure 1 and summarized in Table 1.

Table 1.—Mean results 1947-9, twenty locations. (In percent of GW59).

Variety	Yield of Roots	Sugar Content	Total Sugar
GW59	100.0	100.0	100.0
GW215	102.5	106.8	109.6
C304	111.7	107.3	120.0
LSD 5% pt.	2.2	1.0	2.5

As will be obvious by comparison with GW59, the new varieties show improvement in both tonnage and sugar content, the increases for total sugar being tremendously significant in terms of the mean LSD values at the 5% point.

Variety 304 was tested (Table 1) in the "C" or "pedigreed" generation and reservations were withheld as to final estimates of its potential commercial value in due respect to a preceding study (1942 Proceedings, pp. 342-8, 1942) until a comparison with the commercial or "GW" generation became possible. This was accomplished using seed of GW304 harvested in Arizona in May, 1949, and planted in two locations in early June in comparison

with C304. The results presented in Table 2 represent a total of replications for the two locations.

Table 2.—Late Planted Variety Test. (Mean two locations, 1949.)

Variety	Beets per Acre (tons)	Sugar (percent)	Sugar per Acre (pounds)
GW304	16.00	15.93	5,098
C304	15.91	15.87	5,050
LSD 5% pt.	.85	.42	333

From these data there appears to be no doubt of the equality of the two generations of variety 304.

Several other new varieties having arisen out of this broad program which offer much promise are shown in comparison with C304, three GW commercials and certain other varieties in Table 3, which summarizes results of tests at seven locations in 1949.

Table 3.—General Variety Test, 1949[a]. (Yield and sugar in percent of mean of all varieties.)

Variety	Yield* of Roots	Sugar[0] Content	Total Sugar	Leaf[d] Spot	Percent Bolters
B359	105.7	103.7	109.6	1.5	.07
C305	108.5	100.3	108.8	2.0	0
C304	104.7	103.0	107.9	2.4	.03
B389	101.4	104.0	105.6	1.6	0
GW258	103.0	101.0	103.9	2.8	.03
GW215	98.1	103.5	101.5	2.4	.04
C329	104.4	97.2	101.5	3.9	0
C455	105.2	96.2	101.2	1.4	.47
C381	92.8	106.2	98.6	1.8	0
H-125	98.9	98.9	97.8	3.0	0
R & G "N"	98.5	97.7	96.4	7.2	0
GW59	98.4	96.2	94.7	5.5	.03
GW85	92.7	100.0	92.7	4.3	.07
GW201	91.5	100.5	92.0	5.6	.01
US226	93.4	97.6	91.2	3.1	**.17**
LSD 5% pt.	3.1	1.5	3.5		-

nvith two locations for leafspot and seven locations for all other characters. Six replicates per location.

[b] Mean yield all varieties in test =r 22.98 tons.

[c] Mean sugar content all varieties in test = 15.84 percent.

[d] 0 = immune, 10 z: complete necrosis.

Three new numbers (B359, C305 and B389) are statistically equal to C304 in total sugar production, this being true also in 1948 for B359 and B389 in a four-location test. Further tests will be necessary to determine the comparative value of these four varieties.

Particular attention might be called to certain of the lots in Table 3. GW258 resulted from a recombination of eleven short-rooted inbred lines. C329 is the only lot out of a wide series of crosses with European *Beta maritima* types which has survived the testing program to this time, and it needs some further improvement in resistance to leafspot. C455, resulting from a cross of *Beta maritima* from California with a GW LSR strain (see footnote 2, pp. 175-8, 1948), is a promising number, but it needs some im-

provement in sugar content and further reduction in the annualism or bolting tendency acquired from the *Beta maritima* parent. H-125 is a production by H. L. Kohls of Michigan Agricultural Experiment Station. The lot of R&G "N" used in this test was a 1948 European seed production, and while it proved to be much too susceptible to leafspot, it appeared at least equal to GW Commercial 59 in this series of tests.

One experimental-demonstrational type of test was conducted on a farm at McCook, Nebraska, where leafspot is generally severe. Plots were 8 rows x 1,294 feet, with three replications, all beets being weighed over the dump with samples taken for sugar. Results are summarized in percent of the GW commercial variety 59 in Table 4.

Table 4.—McCook Variety Strip Test, 1949. (Yield and sugar in percent of GW59.)

Variety	Yield* of Roots	Sugar[b] Content	Total Sugar	Leaf[c] Spot
GW59	100.0	100.0	100.0	6.7
GW215	114.7	110.3	126.5	2.0
C304	115.3	109.6	126.4	2.7
GW248	114.6	109.0	124.9	1.7
GW85	114.9	106.6	122.5	4.5
R & G "N"	102.0	98.6	100.5	8-5
LSD 5% pt.	12.0	4.3	13.5	

[a] Mean yield all varieties = 17.12 tons.
[b] Mean sugar content all varieties = 15.38 percent.
[c] 0 = immune, 10 = complete necrosis.

The field was planted rather late in the spring and while leafspot was severe near harvest time, it did not have as much time to take its toll of injury as usual in this area. The superiority of the new LSR numbers over susceptible GW59 and a lot of R & G "N" acquired in 1939 is very striking. In this case, the moderately resistant GW85, which has been the commercial variety in this area in recent years, looked good in comparison with the more LSR numbers—a situation which probably would not hold in a year characterized by an earlier and heavier leafspot epidemic.

From the above results it appears that a new and considerably improved level of performance has been reached for both yield and sugar content in combination with a high degree of resistance to leafspot. At least four of these new numbers have been increased into commercial seed proportions to be in limited use by growers in 1950, and older numbers will be replaced as adequate supplies of the new ones become available.

Other Desirable Characters

Using certain of the choice new LSR numbers, it is planned to improve by selection (either mass or mass plus one generation of selfing) or to introduce into the variety other characters which are known to be valuable but for which little effort has been expended in their behalf previously. These include:

a. Cold resistance[3]
b. Low respiratory activity*
c. Resistance to storage rots
d. Resistance to damping off, black root and mature root rots

[3] Reported in a separate paper in the 1950 Proceedings by the same writers.
[4] Reported in **a** separate paper in the 1950 Proceedings by R. T. Nelson and **R. R.** Wood.

e. **Reduction in number of locules to mono- or bi-locular seed**
f. Small and uniform crown

It is also planned to develop a cytoplasmic male-sterile equivalent of certain of the new varieties in order to facilitate crosses with other varieties, looking toward possible utilization of heterosis or hybrid vigor.

Selection in Self-fertilized Lines

The foregoing program anticipates a continuation of broad breeding methods closely associated with early possibilities for further improvement for particular characters.

The logical next step in our improvement program as it is planned involves an extensive application of the method of breeding so effectively used for corn; viz., that of selection in self-fertilized lines. Some investigations in this field have been conducted, both in Europe and in this country. The practical results to date from this method of breeding have been very limited, and not particularly exciting. We believe this to be due mainly to the fact that the work itself has been far too limited in extent, and that by expanding this work greatly it will be possible to make as great or even greater improvement than that represented by the new varieties reported in this paper as compared with previous commercial types.

There are admittedly certain problems such as partial to complete self-sterility in sugar beets; however, this may be partially overcome by doing the selfing under environmental conditions which are favorable to seed setting under bags or other isolators. This may be considered as a pseudo type of self-fertility. The self-fertility (S^{F}) gene may be employed to assure selfing in some lines.

The sugar beet breeder has one tool available in the form of cytoplasmic male sterility which is proving valuable in making crosses on a commercial scale, and which adds greatly to the assurance of success in an inbreeding and hybridizing program.

Summary

1. Evidence is presented to show a quarter century of improvement in yield and sugar production. In the early years the curve of improvement indicates genetic adaptation. Later improvements were considered to result from a broad search for new genetic sources, selection within these and recombination of the better strains.

2. Recent improvements appear by extensive test to produce as much as 25 percent more sugar per acre than GW18, which originated in 1932 and was the standard variety for much of the Great Western area for several years. These new varieties are very resistant to leafspot, and show improvement in both tonnage and sugar content over previous commercials. They will be in limited use by growers in 1950.

3. Plans for further improvement of these new varieties, as well as application of the method of breeding by selection in self-fertilized lines, are discussed.