Development of Monogerm Varieties of Sugar Beets by the Backcross Method

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Thirty-eight years have elapsed since Harlan and Pope (5)[2] reported the successful use of the backcross method in small grain breeding, and Briggs (3) initiated a similar project in wheat. Since that time, the backcross method has been used rather extensively by Briggs and Allard (4), Suneson (11), and others for self-pollinated crops. As applied to naturally cross-pollinated crops, Richey (6) used the backcross method in a convergent improvement program with corn inbreds, and Stanford (10) employed it in a disease resistance program in alfalfa. This method has been particularly useful for transferring a single character which is simply inherited. For sugar beets it appeared to be a desirable method for the incorporation of the monogerm (single locule seed ball) character into an established commercial variety.

Attempts to develop monogerm strains of beets by the U. S. Department of Agriculture as early as 1903 were unsuccessful. A monogerm character was reported by M. G. Bordonos (1) in 1941 as a simple recessive character. Brewbaker, et al. (2) in 1946 reported the isolation of genetic material characterized by a high incidence of 1- and 2-locule seed balls. This character was later found to vary in its expression with environment, and the material was dropped when the more stable monogerm material discovered by Savitsky (7) became available.

The backcross method was suggested by Savitsky (7) in 1950 for the introduction of the monogerm character into useful commercial varieties. In a later report, Savitsky (9) in 1952 outlined in detail possible techniques for the introduction of this character into commercial varieties. According to his suggested backcross plan, the monogerm plants from the segregating F_2 population, following the second backcross, would become the source of elite seed. Since the original monogerm SL 101 line is self fertile, and self fertility is dominant, his plan called for the selection and use of only self-sterile monogerm plants to make the second backcross.

The backcross method has been followed for the conversion of a Great Western commercial variety from multigerm to monogerm seed type. The first cross between GW304, a Great

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[2] Numbers in parentheses refer to literature cited.

Western leaf-spot resistant variety, and SL 101 was made in 1950, using two potted SL 101 plants supplied from the Salt Lake City station by the Sugar Crops Section of the United States Department of Agriculture. This cross was made by emasculation with a needle of flowers from 16 plants of the GW304 parent and hand pollination with pollen from the two SL 101 plants. For the first backcross the F_1 was used as a pollinator on GW304. Since SL 101 is self fertile and the GW parent self sterile, this backcross produced a population in which self-sterile and self-fertile plants occurred in a 1:1 ratio. The self-fertile plants were eliminated at this point so that self fertility would not appear in succeeding generations. A newly developed Great Western leaf-spot resistant variety (GW674) which was similar in origin but slightly superior to the commercial GW304 used for the original cross was used as the recurrent parent in the second and later backcrosses.

In order to proceed as rapidly as possible in this backcrossing program, each generation was artificially vernalized using low temperature and continuous light so that two generations a year were grown without selection except to recover the monogerm character in segregating F_2 generations. The segregation and approximate ratios for multigerm and monogerm for the generations succeeding the F_1B_1 are presented in Table 1.

Table 1.—Segregation and Ratio of Multigerm to Monogerm Plants in the F_2B_2 to F_2B_6 Generations.

	Multigerm (No.)	Monogerm (No.)	Total (No.)	Multigerm: Monogerm (Ratio)
F_2B_2	747	84	831	8.9:1
F_2B_3	1680	324	2004	5.2:1
F_2B_4	1492	198	1690	7.5:1
F_2B_5	1810	190	2000	9.5:1
F_2B_6 (Pop. A)	2075	521	2596	4.0:1
F_2B_6 (Pop. B)	1330	292	1622	4.6:1

The segregations of the F_2B_2 through F_2B_5 do not closely approach the 3 to 1 ratios obtained by Savitsky (8). This deviation from a 3:1 ratio has also been observed in the conversion of four other varieties. It would appear that modifying genes, in addition to or with greater effect than those Savitsky (7) has postulated for explaining the existence of a few doubles, were present in the GW commercial varieties used as the recur-

rent parents. In the F_2B_6 two different populations produced ratios of 4.0 and 4.6 to 1, respectively. These narrower ratios could be explained because the parental monogerm plants used to produce the F_1B_6 were carefully selected for freedom from doubles.

The backcrosses were made using pollen from one monogerm plant in the F_2B_1 generation, and for the succeeding generations a mixture of pollen was used from all available monogerm plants as shown in Table 1. About 200 plants of the recurrent parent were used for each backcross. The number of F_1 plants used to produce the segregating generations varied from about 200 in the B_2 to 600 in the B_5 and B_6 cycles.

The general procedure used in this backcross program is shown in Figure 1.

It will be noted from Figure 1 that six successive backcrosses have been made, and from Table 2, that tests have been conducted on monogerm varieties derived from the second to the fifth backcross. Since seed of SL 101 has not been available in quantity for extensive field testing, all comparisons of performance in replicated trials have been made only with the recurrent parent, GW674, with results as summarized in Table 2.

The results in Table 2 are summarized from variety tests with 12 replications of 54 feet of row per plot in 22 inch rows. Each test was conducted at two locations in 1958 and three in 1959 for the B_2 to B_5 generations in comparison with the GW674 parent; also for four observation plots for SL 101 in comparison with GW674 in the same series of plots. For yield of roots and

Table 2.—Mean Performance of Monogerm Backcrosses in % of GW674 in 5 Tests—Two in Colorado in 1958 and 1959 and One in Nebraska in 1959[1].

Variety	Yield of Roots	Sugar Content	Gross Sugar	Thin Juice Purity	Recoverable Sugar
GW674 MM	100.0	100.0	100.0	100.0	100.0
B_5 mm	101.7	100.4	102.1	99.8	101.8
B_4 mm	97.3	101.2	98.4	100.1	98.7
B_3 mm	94.1	99.1	93.4	99.8	92.9
B_2 mm	89.3	99.7	89.0	99.4	88.6
SL101[1]	48.8	104.3	51.0		
LSD 5% pt.	2.7	1.2	2.9	0.4	2.9

[1] For SL 101, data are summarized from one observation plot in 1958 and three such plots in 1959.

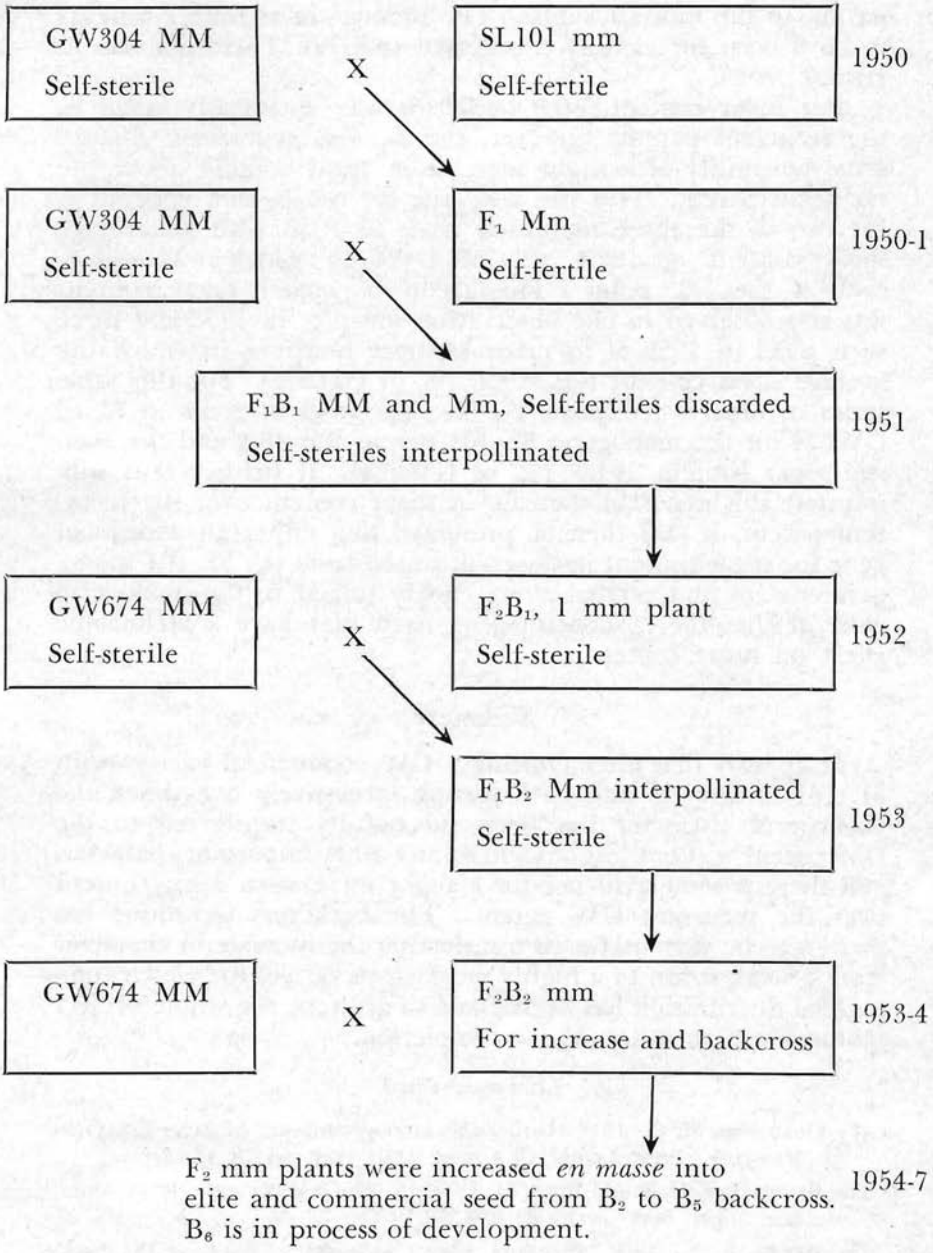

Figure 1.—Outline of procedure used for converting GW674 to monogerm by the backcross method.

total sugar, there appears, as expected, a gradual increase from the second to the fifth backcross. The monogerm character appears to have been successfully transferred to GW674 without loss in yield.

For sugar content, each backcross was statistically equal to the recurrent parent; however, the B_4 *mm* generation showed some possibility of a slight increase in sugar content above the recurrent parent. This was also true for the B_5 *mm* generation for two of the three replicated trials in 1958 with an average sugar content of 102.4 (% of GW674), which was significant at the 5% point. This trend of higher sugar content was also observed in one observation test plot in 1958 and three such plots in 1959 at as many separate locations in which the average sugar content was 104.4 (% of GW674). For this same series of observation plots, the average yield of roots in % of GW674 for the monogerm SL 101 parent was 48.8 and the average sugar content 104.3 (% of GW674). If further tests substantiate this apparent increase in sugar content over the recurrent parent, it may then be presumed that either an additional gene for sugar content has been acquired from the SL 101 monogerm parent and carried along closely linked to the monogerm gene or that the monogerm gene itself may have a pleiotropic effect on sugar content.

Summary

It appears that after crossing a GW commercial variety with SL 101 monogerm and backcrossing successively five times, the monogerm character has been successfully transferred to the GW parent without loss of yield or any other important character, and there is some evidence for a slight increase in sugar content over the recurrent GW parent. The backcross technique has proven to be very useful in transferring the monogerm character from a weak strain to a highly satisfactory variety for which commercial distribution has been made to growers, the whole project taking less than a decade for completion.

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