Methods and Results of Breeding Work With Monogerm Beets

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Introduction

This report is based on a study of the inheritance of the monogerm character and a study of hybrids derived from the original monogerm line SLC 101. Introduction of monogerm sugar beets into commercial use will decrease the quantity of seed used for planting, but will increase requirements for improved seed quality. The quality of monogerm seed can be improved significantly by sorting and cleaning machines. Demands which will be made for improved size and weight of monogerm seed and for increased vigor of seedlings will make it necessary to develop the most appropriate agronomic methods for seed production which will produce seed of the highest quality. However, the main problems in this field must be solved by breeding work.

Variability of Absolute Weight of Monogerm Fruits and Breeding Work with this Character

Different varieties of *B. vulgaris* L. are not distinguished very much by size and quality of fruits, but large variations in fruit or seed-ball characters are manifest within each population. Therefore, inbred lines and clones originating from the same variety are very diverse for seed characters (3).[2]

In all beet varieties, the weight of seed-balls increases in proportion to the number of flowers in the flower cluster which goes to form the seed-ball. The coefficient of correlation for these two characters varies within populations from 0.4 to 0.7. The same correlation was observed for different plants within a clone. Environment can modify both of these characters. The intervarietal and inter-biotypical correlation makes breeding work very difficult for size of fruits and seedlings in multigerm beets. The study of inheritance and variability of the weight of fruits is facilitated now because of the new monogerm beets.

The pronounced correlation between number of flowers per flower cluster and weight of seed-balls for F_2 multigerm segregates derived from five different crosses between multigerm and monogerm beets is illustrated in Figure 1. These F_2 multigerm segregates from the five different crosses also showed different average weights per 1,000 seed-balls, even when the number of flowers per flower cluster was the same (Figure 1).

The variability of the weight of fruits in monogerm beets differs from the variability in multigerm plants. Because of the correlation between number of flowers per seed-ball and the weight of seed-balls in multigerm beets, one might expect that monogerm plants would develop very small fruits. In fact, the weight of 1,000 seed-balls from multigerm beets was on the average two grams more than the weight of 1,000 monogerm fruits from

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[2] Numbers in parentheses refer to literature cited.

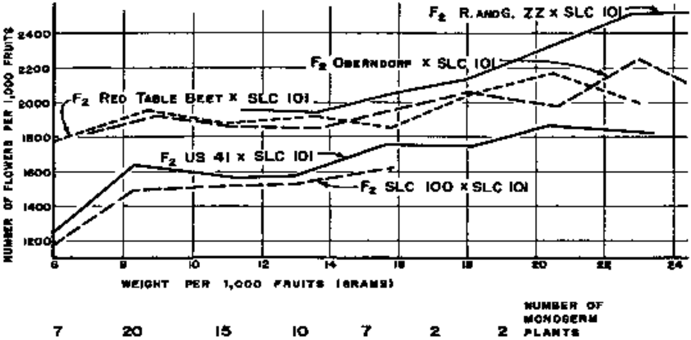


Figure 1.—Correlation between number of flowers per flower cluster and weight of 1,000 seed-balls in multigerm F_2 segregates from five different F_2 populations. The same five F_2 populations also produced 63 monogerm segregates. A frequency distribution showing the weight of 1,000 seeds from each of these 63 beets is shown at the base of the figure.

the same five F_2 populations (Table 1). The coefficient of variation for the weight of 1,000 fruits from different F_2 monogerm plants was 14.9 percent; for the multigerm segregates from the same population this coefficient was a little lower, 13.9 percent. Because of the larger variability of the weight of fruits in the monogerm F_2 segregates, the amplitude of their variation approaches the amplitude of variation for the weight of 1,000 seed-balls in multigerm beets. Therefore, individual monogerm races can develop large as well as very small fruits. In F_2 populations segregating for multigerm versus monogerm plants, the majority of monogerm plants was found to produce small fruits (Table 1). Selection of monogerm plants for size of fruits in F_2 and F_3 is possible and is necessary since in 1951 experiments the weight of 1,000 fruits of monogerm plants varied from three to 34 grams. In spite of large variability in fruit weight from different genotypes, the weight and size of monogerm fruits from one monogerm plant or inbred line were more uniform than the same properties of fruits from multigerm beets. The uniformity of fruits on double-germ beets was

Table 1.—Weight of 1,000 Fruits in Monogerm and Multigerm F_2 Segregates (SLC 101 x Multigerm Beets).

	Classification of F_2 plants on average weight per 1,000 fruits (in grams)										
F_2 segregates	4 g.	6 g.	8 g.	10 g.	12 g.	14 g.	16 g.	18 g.	20 g.	22 g.	Total plants
	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	Number
Monogerm plants	3	4	20	15	10	7	2	2			63
Multigerm plants		9	22	43	39	36	20	13	4	1	187
Total plants	3	13	42	58	49	43	22	15	4	1	250
	%	%	%	%	%	%	%	%	%	%	
Monogerm plants	100	31	48	26	20	16	9	13	0	0	

intermediate to the uniformity in mono- and multigerm plants. This can be explained by the differences in the values of the coefficient of variation for the number of flowers per flower cluster. In multigerm beets this coefficient was found to be 31 percent; in double-germ races it decreased to 20 percent because double-germ plants produce some monogerm fruits and some fruits with three flowers.

An experiment in 1949-1951 showed that selection for weight of fruits was successful in multigerm as well as in monogerm beets. Selection can be based on the size of fruits (diameter or weight of fruits) and on the type of inflorescence. The latter makes it possible to select plants before flowering.

Breeding work for increased weight and size of fruits can contribute towards increased tonnage. The best backcross hybrids which produced high yield were obtained when the recurrent multigerm parent was selected for size of seed and for a particular type of inflorescence.

Selection for size of fruits among monogerm F_2 segregates showed that 92.8 percent of the selected inbred monogerm S_2 lines showed good germination and seedling vigor in the field. About 10 percent of the selected inbred lines were low in germination percentage and seedling vigor. It may be as well to accompany selection for weight of fruits by a study of seedling vigor in laboratory tests.

Selection for improved size and quality of monogerm seed should be made in the first hybrid generations when the monogerm segregates are selected.

Development of monogerm varieties can follow different breeding methods, descriptions of which follow.

Method of Obtaining Monogerm Varieties from F_2 and F_3 Lines

The simplest way to obtain monogerm varieties is directly from F_2 and F_3 lines (Figure 2) as follows: Crossing of valuable multigerm varieties with the monogerm race, open pollination or selfing of F_1 hybrids, and selection for monogerm segregates in the F_2 generation. It has been assumed advisable to plant seed from each monogerm plant separately for critical tests. Elite monogerm seed is obtained from a mixture of the progeny of the best F_3 lines. Selection of monogerm plants in the F_2 generation is also suitable when inbred lines from selected plants are developed and commercial seed showing heterosis is raised from these lines.

Selection of monogerm beets in the F_2 generation will acquire still larger significance when not only self-fertile, but also self-sterile, monogerm beets can be used in the breeding program. Then in two or three generations mass and individual selection will make it possible to obtain new monogerm varieties.

The Backcross Method

The American as well as the European sugar industry needs many different varieties which are resistant to different diseases, which are adapted to different climates and different agricultural conditions. In all these varieties the multigerm fruits must be changed to monogerm. This enourmous work can be accomplished by using the backcross method.

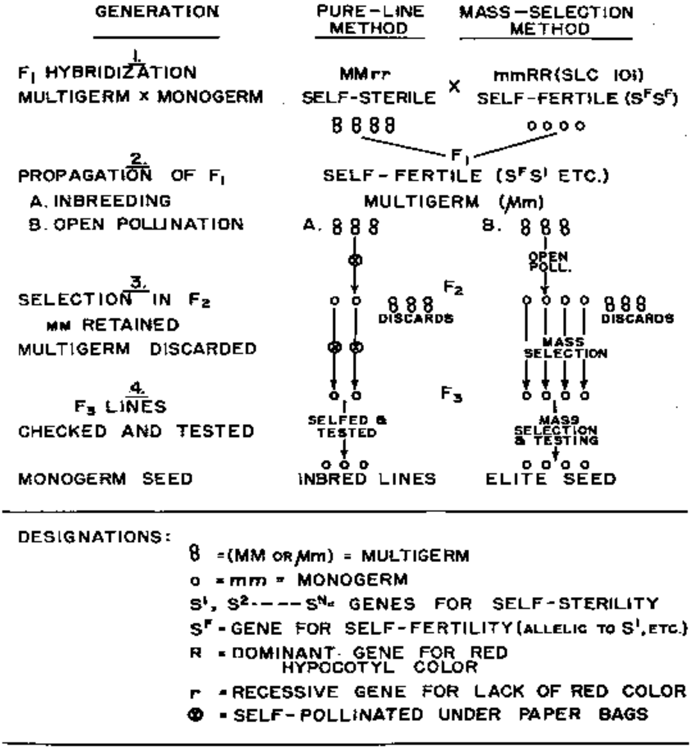


FIGURE 2.
OBTAINING MONOGERM VARIETIES FROM F_2 AND F_3

When only sugar-beet varieties (not red table beet or fodder beets) are involved in the breeding work, usually one or two backcrosses are sufficient. Hybridization of SLG 101 with different varieties showed that even the first backcross formed very valuable populations for selection of monogerm plants. When curly-top-resistant varieties were involved in the crosses, the degree of curly-top resistance in b_1 populations nearly approached the level of resistance of the highly resistant varieties. The same b_1 populations showed good yield and sugar percentage when the multigerm parents were luckily combined. The b_1 generation is also the most suitable generation for selection of self-sterile beets as shown in experiments of Dr. H. Savitsky (2) .

A further increase in the number of backcrosses complicates the selection of monogerm plants as well as selection for sugar percentage and yield. In a self-sterile population the percentage of monogerm segregates drops from 6.5 to 1.56 when reproductions are made from the first and second backcross generations respectively. It is better to make the second backcross to multigerm beets when necessary after monogerm plants have been selected in the $(b_1)_2$ generation (Figure 3) . This scheme can be applied also to the development of monogerm varieties for resistance to curly top and also for the development of self-sterile monogerm varieties.

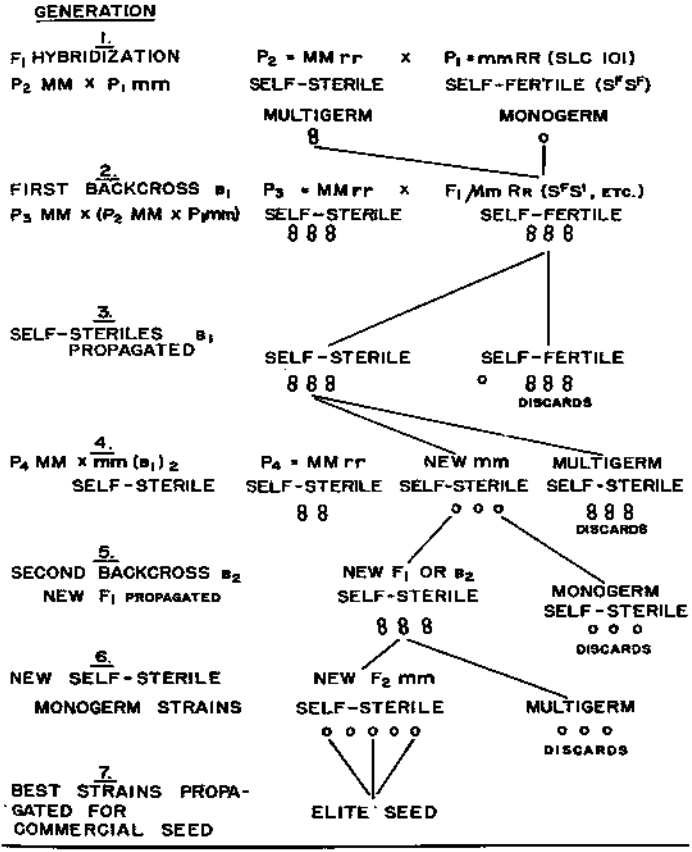
Selection for self-sterile plants should be started in the first backcross generation (b_1) , and self-fertile plants discarded. It might be well to harvest the seed from self-sterile b_1 plants separately, because only 50 percent of these plants will carry the gene *m* in the heterozygous condition. In the next generation the self-sterile plants will segregate for monogerm and multigerm beets. The latter must be discarded before flowering.

The monogerm plants selected for self-sterility in the $(b_1)_2$ generation to be crossed under open pollination should be grown adjacent to a multigerm pollinator. This is the second backcross. An examination for self-sterility of the selected plants may be made in the next generation; only hybrid multigerm plants will be retained for further work. These plants will segregate in the next generation for multi- and monogerm self-sterile plants. Seed from these new self-sterile monogerm plants must be harvested separately. A mixture of seed from the best monogerm lines will give elite seed by this method in six or seven generations. This seed represents the product of two-fold selection and two-fold backcrossing.

Inbreeding and Heterosis

The inbreeding method is very valuable for incorporation of genes responsible for new properties (non-bolting tendency, resistance to disease, size of fruit, desirable shape of root, etc.) and also for making use of the effect of heterosis. Self-fertile monogerm inbred lines in the S_3 to S_5 generation of selfing derived from hybrids with SLC 101 can be utilized for:

1. building a population from a mixture of the best inbred lines which can partially intercross under open pollination; 2. development of special male-sterile inbred races and two types of pollinators for them. The first pollinator must be an inbred line of type 0 (1) in order to produce completely male-sterile offspring. If this line is uniform, the male-sterile line in a few generations of backcrosses will become more or less equivalent to the hermaphrodite line. The second pollinator may be used to obtain commercial seed. Any multigerm or monogerm beets, inbred lines, varietal populations, F_1 hybrids or triple hybrids, may be used as a second pollinator; the only requirement is that it produce heterosis when crossed to the male-sterile line. The majority of the contemporary varieties and inbred lines do not belong to type 0. Dr. F. V. Owen's investigations indicated that SLC



OBTAINING SELF-STERILE MONOGERM STRAINS AND VARIETIES BY THE BACKCROSS METHOD
(FOR DESIGNATIONS SEE FIGURE 2.)

FIGURE 3.

101, when crossed with different varieties, can produce F_2 plants belonging to type 0.

If the male-sterility method is used in the breeding program with monogerm beets, it is necessary to develop two types of hybrids at the same time: 1. backcrosses to male sterile to obtain male-sterile monogerm races, and 2. hybrids to obtain monogerm pollinators which can give 100 percent male sterility in the progeny of MS plants during their propagation. The male-sterile monogerm beets must produce good fruits, because these fruits represent commercial seed.

Summary

The effectiveness of breeding work with monogerm beets by any breeding method depends upon genetical diversity for valuable properties in the initial material used in the breeding program. The large genetic diversity in the species *B. vulgaris* L. opens up new perspectives for improvement of sugar percentage, tonnage, quality of seed, vigor of seedlings, etc., simultaneously with breeding for the monogerm character.

These comprehensive methods have been used in breeding work with hybrids derived from crosses of the monogerm beet SLC 101 with different sugar beets, red table beets, fodder beets and Swiss chard. Many new inbred lines and populations of monogerm beets were obtained as a result of this work. These new monogerm strains showed a large variation in size and type of fruits, in earliness of bolting tendency, in sugar percentage and tonnage. Curly-top-resistant monogerm strains were selected among them. Dr. F. V. Owen obtained male-sterile monogerm strains and Dr. H. Savitsky developed self-sterile monogerm beets. The writer obtained beets in which the monogerm character was combined with characters of red table beets, fodder beets and Swiss chard. The presence of diverse types of monogerm beets now makes it possible to start breeding work within monogerm strains by applying different breeding methods.

Every sugar-beet breeding station must have at its disposal, in addition to self-fertile monogerm beets, also 1. monogerm beets resistant to the main diseases of the area, 2. male-sterile monogerm beets and appropriate pollinators for them, and 3. self-sterile monogerm beets. Transference to all sugar-beet breeding stations of these new breeding stocks will help them to expedite the development of new monogerm varieties.

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