Utilization of Male Sterility in Breeding Superior-Yielding Sugar Beets

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IT HAS NOW BEEN well demonstrated that hybrid sugar beets can be produced which are superior in yielding ability to the curly-top-resistant varieties now in commercial use. Data obtained from male-sterile hybrids in 1945 (3)[2] show a significant increase in yield over standard commercial varieties. These results were repeated in 1946, and in 1947 still better results were obtained with more recent hybrids. The seed supplies of these male-sterile hybrids have not as yet been produced in commercial quantities but there is a possibility of this in the not too distant future.

Male sterility in sugar beets may be inherited in different ways. The type of male sterility most useful to the breeder is inherited cytoplasmically. Pure cytoplasmic inheritance has the advantage of being simpler than Mendelian inheritance as far as the rules of superficial analysis are concerned. However, the underlying basis of cytoplasmic inheritance is not fully understood and it has only recently attracted widespread interest among American geneticists. In the present paper it will suffice to deal with the simple rules of the inheritance of the cytoplasmically inherited male sterility that apply to practical breeding problems.

Male-sterile beets are represented by the designation MS. These beets are fertile as females but completely sterile as males and they can, therefore, be used only as females in hybridization work. Artschwager (1) has recently described the abnormal development within the anther responsible for the male sterility.

How Male Sterility is Inherited

Male sterility, to be useful in breeding work, must be easily obtained. Accurate predictions regarding the constitution of progenies from respective crosses are particularly important. Male sterility is most useful when progenies can be produced in which 100 percent of the beets are completely male-sterile. Inheritance studies have shown that such progenies are not only possible but are also common among controlled crosses to the male-sterile beets. Unfortunately, some crosses to the male-sterile beets do not produce uniformly male-sterile offspring and genic effects have been recognized (2) which appear to modify the expression of the cytoplasmic inheritance. These complications make it necessary to conduct extensive tests to determine which progenies can be depended upon to produce completely male-sterile offspring.

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[2]The numbers in parentheses refer to literature cited.

Three general types of pollen parents will be designated O, I, and II. These pollen parents are normal hermaphrodite beets and can be used either as females or as pollen parents. Here they will be considered principally as pollen parents. The O, I, and II beets can not be distinguished by their appearance; they differ only in breeding behavior (table 1).

Table 1.—Breeding behavior of three genotypes O, I, and II.

Parents			Offspring
♀		♂	
MS	×	0	all MS
MS	×	I	mostly MS (5 to 30 percent semi-MS)
MS	×	II	50 percent MS 25 percent semi-MS 25 percent more or less normal

In successive backcrosses to type O, male sterility is inherited entirely through the female parent as shown in figure 1.

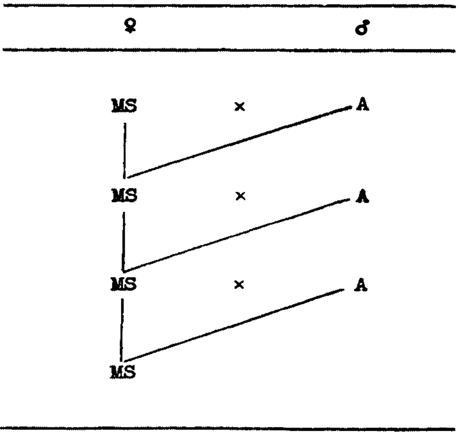

Figure 1.—Inheritance of male sterility in successive backcrosses to type 0; all offspring are male-sterile.

Succeeding generations of MS females crossed to type O beets are all completely male-sterile. Type O is the desirable type when one wishes to propagate male-sterile beets. Types I and II are undesirable. To avoid these undesirable types preliminary crosses are necessary so that the objectionable types may be discarded. In some commercial sugar beet varieties about 50 percent of the beets are type O. To distinguish and preserve these desirable type O beets, they must be clonally propagated or else they must be self-pollinated. A third method of crossing two self-sterile beets in pairs can be used. Preservation of type O beets by self-pollination has many advantages. Besides preservation of the desirable O type, selfing also makes possible a new and powerful approach to the problem of isolating superior genotypes of sugar beets.

Methods of Hybridization

There are several methods of hybridization available to the sugar beet breeder in the utilization of male sterility. First, it is necessary to rogue out undesirable beets that are not completely male-sterile. The first populations of male-steriles may be mixed with intermediate or semi-male-sterile beets because of type I and II pollen parents. In seed isolations roguing can be accomplished before the flowers open by using a sharp knife and cutting into well-developed floral buds. After building up reliable male-sterile populations it is possible to consider extensive backcrossing procedures always utilizing the male-sterile as the female parent.

The curly-top-resistant inbred sugar beet designated CT9 was the first inbred to be extensively investigated with regard to hybridization with male-steriles. The first hybrids were made with CT9 as the pollen parent. These hybrids gave such promising results that a series of backcrosses to the inbred parent were initiated.

The backcrossing procedure is illustrated in figure 2.

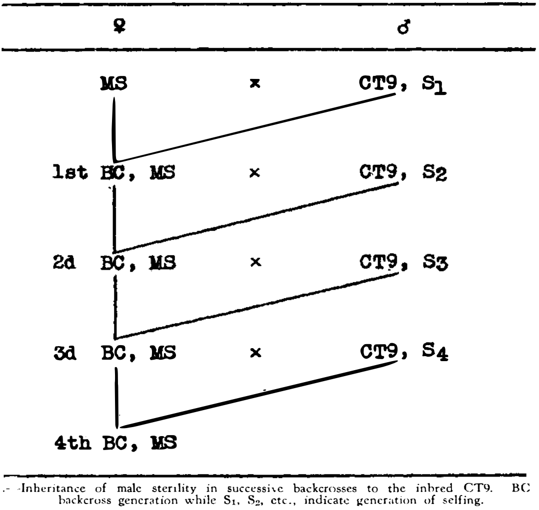

Figure 2.—Inheritance of male sterility in successive backcrosses to the inbred CT9. BC indicates backcross generation while S_1, S_2, etc., indicate generation of selfing.

The second and third backcross to the male-sterile produced MS beets strongly resembling the CT9 inbred. A fourth backcross was produced in 1947. The third and fourth backcross generations may, for practical purposes, be considered MS equivalents of CT9.

After an MS equivalent of CT9 was obtained, it was possible to utilize the CT9 genotype as a female parent. Formerly it could be utilized only as a pollen parent. High-yielding hybrids were produced regardless of whether CT9 was used as the pollen parent or whether the male-sterile equivalent of CT9 was used as a female parent. In several replicated tests in 1947 all CT9 hybrids produced more sugar per acre than standard commercial varieties. In some instances this increase amounted to over 20 percent.

The hybrids with CT9 so far produced are similar to what have been termed top crosses in corn, in other words, one of the parents was an open-pollinated variety. Hybrids between properly selected inbred lines should be superior to top crosses. Three-way hybrids between inbred sugar beets may have possibilities. This involves the production of the male-sterile equivalent of one of the lines and the selection of a second inbred of type O. The scheme is illustrated in figure 3.

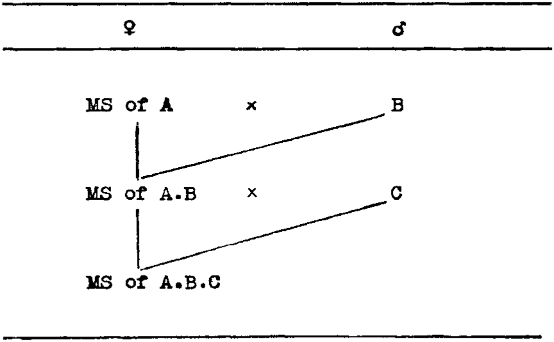

Figure 3.—Production of a three-way hybrid from the inbreds A, B, and C.

Male sterility may also be used to facilitate other desirable hybrids. Tetraploid sugar beets have now been produced by several investigators. Hybrids between tetraploids and the usual diploids produce triploids. Excellent vigor has been obtained in preliminary experiments with these triploid hybrids. This and other types of hybridization work can be facilitated by utilization of male sterility.

Male Sterility in Relation to Inbreeding

The manner in which inbred lines can be utilized with male sterility reverses much of the line of thought in sugar beet breeding. Homozygous inbreds, which heretofore have been interesting but without value, suddenly become of great value. Inbred lines like CT9 are so highly self-fertile that they cannot be hybridized directly. When beets from two of these lines were grown together they did not hybridize more than about 10 percent and sometimes much less than this. This high degree of self-fertility, together with the resulting homozygosity and lack of vigor, makes the inbred lines worthless within themselves. Their value, like that of the corn inbreds, is dependent upon their yield prepotency. All inbreds are not expected to have high-yield prepotency. The breeder's task is to sort out the good from the bad and to select inbreds for hybridization which have high-combining ability or yield prepotency. Useful inbreds must also possess desired qualitative characters such as disease resistance, root shape, etc. Inbreeding greatly facilitates the attainment of these desired qualitative characters. By means of hybridization through male sterility, inbred lines of sugar beets can be utilized in much the same way that inbred lines of corn have been so widely utilized.

Summary

Hybridization in sugar beets by means of male sterility has promise of being a practical procedure because of the fact that the inheritance of certain types of male sterility follows relatively simple rules. These rules are simple because they are governed chiefly by cytoplasmic inheritance rather than by the more complex rules of Mendelian inheritance. The simple rules of cytoplasmic inheritance have made it possible to establish male-sterile equivalents of many curly-top-resistant strains and varieties and of some inbred lines. The method does not work with all inbred lines because some beets apparently carry genes which modify the expression of the cytoplasmic inheritance. It is necessary to avoid these objectionable genes by means of progeny tests. As a rule about 50 percent of beets selected at random do not carry the objectionable genes. The curly-top-resistant inbred line CT9 is an example of a relatively desirable inbred.

Different methods of hybridization with CT9 have been illustrated. It is important now to develop more and better inbred lines. It is also important to explore the possibility of obtaining superior hybrids by bringing together genotypes from diverse origins. Cytoplasmically inherited male sterility facilitates hybridization work of many kinds. It is an invaluable tool in genetic investigations and also has promise of being useful in producing high-yielding hybrids on a commercial scale.

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