The Sugar Beet Breeder's Problem of Establishing Male-Sterile Populations for Hybridization Purposes

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Cytoplasmically inherited male sterility in sugar beets offers many advantages to the sugar-beet breeder provided the desired male-sterile populations can be made readily available to him. Genes which interfere with, or which are complementary to, the cytoplasmic inheritance deserve special consideration. Evidence indicates the operation of at least two such genes, one of which may be considered to have a major influence and the other a minor influence. Certain hermaphrodite beets, designated type O (3)[2], when used as pollen parents in crosses to male steriles, produce offspring all of which are completely male sterile.

Genetic Interpretations

With information available the inheritance of this type of male sterility in beets may be considered to be approximately as follows:

N = normal cytoplasm
S = male-sterile cytoplasm
X = major gene
Z = minor gene

All genotypes carrying N cytoplasm are normal pollen producers regardless of the *X* and *Z* genic constitution. Type O hermaphrodites may be considered to be *Nxxzz*. Completely male-sterile beets are assumed to be *Sxxzz*. These *Sxxzz* females crossed with Nxxzz hermaphrodites produce the desired Sxxzz populations. The presence of X or Z with S cytoplasm presents a complicated situation with many intermediate semi-male-sterile types, some of which may be more or less normal pollen producers.

Indexing Hermaphrodite Stocks

Indexing of beets to determine the "type O" or Nxxzz hermaphrodites requires some method of preserving the genotypes until their hybrids to male steriles can be forced to flower so they may be classified properly for male sterility. Both vegetative clones and self-fertile lines are especially useful for this purpose. In preliminary indexing work on a large scale, it is difficult to avoid errors, but any procedure which increases the proportion of Nxxzz genotypes in a population may be helpful. In self-sterile populations known to possess a high proportion of Nxxzz individuals the beets may be crossed in pairs with an index made from each member of the pair. Methods of obtaining selfed seed from partially self-fertile beets should have good possibilities in connection with this indexing work.

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[2] Numbers in parentheses refer to literature cited.

Frequency of Nxxzz Hermaphrodites

Fortunately, the much desired Nxxzz hermaphrodites appear to be rather common in commercial varieties of sugar beets, at least in the curly-top-resistant varieties investigated by the writer. In a previous publication (2), reference is made to progeny tests with 91 beets taken at random from these varieties. The progeny tests indicated that 27 of the 91 beets were of constitution Nxxzz. Later work has shown that preliminary tests do not always differentiate between Nxxzz and NxxZz hermaphrodites because of the small effect of the minor Z factor which can not be detected readily. Theoretically, one might assume that NXXZZ and Nxxzz hermaphrodites would appear with equal frequency, but experience has indicated that this is not the case. For unknown reasons the NXXZZ types have rarely if ever occurred while Nxxzz hermaphrodites have been detected frequently. Genotypes of possible constitution NxxZz were predominant in one year's progeny tests from beets of variety US 35/2.

Homogenic Male-Sterile Populations

Building up reliable homogenic male-sterile populations is an important procedure in connection with the indexing work. Data presented in Table 1 illustrate the danger in assuming that all male-sterile beets have the same Sxxzz constitution. Some beets which may be considered SxxZz in constitution may appear completely male sterile and slight environmental variations may make a considerable difference. Furthermore, some results indicate that certain complementary genes possess a dominant rather than a recessive influence. Individuals taken from populations, all individuals of which are completely male sterile, have a greater chance of being homogenic than if they are taken from a segregating population. It appears safer to work with old reliable male-sterile populations rather than to take too many chances with new untested populations.

Table 1.—Effect of different male steriles crossed with the same pollen parent.

Male-sterile female	Pollen parent	Male sterile	Semi-male sterile No. 2	Semi-male sterile No. 3	Normal pollen producers
		Number	Number	Number	Number
03 MS[1]-1	CT9-61	31	15	4	0
03 MS-2	do.	24	0	0	0

[1]03MS represents the F_1b_1 or first backcross generation to the annual inbred 03.

Use of Annual Growth Habit

At Salt Lake City a self-fertile annual inbred has been developed of possible constitution Nxxzz. This inbred, designated "03" is recessive *(rr)* for hypocotyl and crown bud color which is an added convenience. Male-sterile F_1 hybrids with 03 were used for indexing work in 1948. The first male-sterile backcross population was used in 1949 and the second male-sterile backcross is being grown for use in 1950. These annual male-sterile *rr* beets have decided advantages for indexing work with the facilities available at Salt Lake City. A large number of plants is held vegetative under short winter days in the greenhouse and groups of the plants are brought into flower under long photoperiods at regular intervals to correspond with the development of the hermaphrodite breeding stocks to be tested. With facilities available at Salt Lake City it is impossible to control the flowering of biennial beets as easily as that of the annuals.

After a series of hybrids to unknown hermaphrodites is completed, the breeder is eager to force the new progeny to the flowering stage as rapidly as possible. The dominant annual or *B* factor (1) is helpful in this respect. The better the facilities for long photoperiods with good light quality and intensity, the more rapid the flowering for the F_1 annual beets. At Salt Lake City this indexing work was completed with these annual beets in February and March, but some preliminary trials with artificial light during the summer indicate that the same information might be made available the previous September.

Effects of Contamination

It is difficult to avoid all sources of contamination in connection with extensive indexing work. In making the test crosses to male steriles by means of paper bags, there are advantages in the greenhouse cultures to avoid insect troubles and weather hazards. It is advisable to hold open pollen-producing inflorescenses to a minimum. Some measure can be made of the amount of contamination by using *rr* MS females. In *rr* 9 x *rr* <? combinations in the presence of possible contaminating R pollen, the appearance of R seedlings in the offspring gives an estimate of the amount of contamination. Likewise in *rr* 9 x *RR* cf combinations the appearance of *rr* seedlings gives an equally valid estimate of contamination. At Salt Lake City in 1949 there were 95 such progenies and the average contamination was estimated to be 0.3 percent. As long as there is a source of contamination, occasional unconformity to expected results must be expected and allowed for.

Need for More Information

There is need for more information regarding the cytoplasmically-inherited male-sterility in beets, both with regard to the constitution of the cytoplasm and the genic constitution which may modify the cytoplasmic influence. There is no absolute assurance that all sources of the male-sterile beet carry the same cytoplasm, and evidence indicates quite definitely that the influence of more than two genes may be encountered with variable types of influence. It is important that different sources of male-sterile beets be studied carefully to determine what differences may exist. There is even a possibility that the whole theory may need revision when more information is obtained.

Summary

Male sterility offers great opportunities to the sugar beet breeder; it also offers many challenges. A technical, but nevertheless important consideration, is the breeder's ability to produce pure homogeneous male-sterile populations. As little as one percent of pollen producers in male-sterile populations is not considered satisfactory for certain types of hybridization work. The presence of pollen producers necessitates careful roguing before flowers open to assure complete hybridization.

Indications are that pure male-sterile populations may be obtained by careful attention to pedigree records. Certain hermaphrodite beets, designated type O, when used as pollen parents in crosses to male steriles, produce offspring all of which are completely male sterile. Such hermaphrodites may represent the double homozygous recessive for two or more genes whose effect is complementary to that of the cytoplasmic influence.

The breeder's task is to index adequately his hermaphrodite populations in order to recognize the desired type O beets. Several problems of technique are involved in this process and some difficulties have been encountered. More trouble seems to be caused by the gene, or genes, with the minor influence because it is more difficult to detect. One useful procedure has been the incorporation of male sterility into an annual beet whose flowering can be induced without the use of low-temperature treatments.

Literature Cited

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