VARIABILITY IN THE SPECIES BETA VULGARIS L. IN RELATION TO BREEDING POSSIBILITIES WITH SUGAR BEETS[1]

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The species of beets known as *B. vulgaris* includes sugar beets, mangel wurzels, red table beets and Swiss chard. For practical purposes most forms of the wild beet, *B. maritima*, might also be included, because nearly all these beets cross readily with the domesticated varieties. This represents a great range of variability. Much variability also exists within varieties. The extent of this genetic variability accounts for the success of previous efforts in applied breeding work, and it indicates the existence of a valuable source of biological material that may be molded into more valuable forms in the future.

While recognizing this genetic variability an equally great source of environmental variability must also be considered. Beet development is so strongly dependent upon environmental conditions that a study of heredity and environment must go together.

It should not be implied, however, that environmental variability always represents a handicap in connection with breeding work. When properly understood and controlled, environmental influences may constitute an invaluable aid to the breeder. This point may be illustrated by relating some experiences in breeding beets for resistance to the virus disease known as curly-top. Twenty five years ago the possibility of producing curly-top-resistant varieties of sugar beets was something that nobody was too sure about. Progress was slow at first and improvements in degree of resistance were small. By 1928, Carsner and Pack (3)[3] had brought together several strains with slight to moderate degrees of resistance. In 1929 the important decision was made of mixing all of these strains together. The resulting mixed variety was designated U. S. 1. The significant thing about this heterogeneous material, from the geneticist's viewpoint, was the occasional appearance of what seemed to be highly resistant individual beets. Back in 1930 and 1931 there were arguments about whether these outstanding individual beets

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3/Figures in parentheses refer to "Literature Cited," p. 149.

were really as resistant as they appeared, whether they escaped infection altogether, or whether they were influenced in their growth by some special environmental factors. It was eventually learned that their development was affected by both environmental and heritable influences.

More recent progress with curly-top resistance has been most significantly affected by a better knowledge of the environmental variability. It was learned that young beets were more easily infected than older beets and that the disease became more severe in hot weather than in cool weather. This information has made it possible to establish drastic curly-top exposures in mid-summer plantings.

These drastic exposures have been found to have a profound effect upon selection and evaluation work. Under mild or only moderately severe exposures, curly-top resistance has the appearance of a dominant character. When hybrids between resistant and susceptible types were tested under the less drastic environments, the F_1 plants resembled the resistant parent (1). Under the more drastic exposures now made possible by mid-summer plantings, dominance is lacking, and the F_1 hybrids resemble the susceptible parent much more than the resistant parent. Hence, the character might now be regarded as recessive rather than dominant. When selections were made under the less drastic environments where the F_1 hybrids could not be distinguished, segregation for relatively susceptible types were expected in the next generation. Under the more severe curly-top exposures, heterozygous individuals can be detected and eliminated.

A study of environmental variability is equally important in connection with breeding for resistance to any of the other beet diseases. Such studies are particularly significant in connection with breeding for increased resistance to bolting. Progress is impeded in connection with breeding for increased yield or sugar percentage because so little is known about controlling environmental variability.

The mechanization of harvest operations raises new problems and no doubt the breeder can be helpful, but there are likely to be disappointments if environmental variability is not fully recognized. Perhaps the most important thing the breeder can do is to increase genetic uniformity. It will take work to produce varieties of beets with uniformly shaped roots and with uniform crowns and foliar growth, but there are definite indications that this goal can be accomplished.

Genetic variability is also important in connection with characters that might be designated as breeders' tools. These characters do not affect yield directly, but they determine to a large extent what a breeder can plan to do in the way of developing breeding methods. One of the most convenient tools consists of a simple hypocotyl color character commonly used for a marker. In hybridization work the use of this character makes it possible to plan systems of matings whereby desired hybrids can be distinguished from other offspring which may not be hybrids.

Beets are especially variable with regard to sterility and incompatibility relationships. Most sugar beets are inclined to be strongly self sterile, unless one provides an environment to induce selfing. Highly self-fertile types of beets exist, however. A type of self fertility found in one of the early curly-top-resistant varieties appears to be determined by a single gene. With a knowledge of the rules of the oppositional hypothesis, this gene for self fertility can be readily transferred to any material where it is desired (4). This high degree of self fertility is even more noticeable in the vigorous F_1 hybrids than in the less vigorous beets obtained after selfing.

Male sterility may become another important breeders' tool. It facilitates hybridization work, and for this reason it is useful in connection with many types of investigations. There are different types of male sterility in beets, but the most useful type appears to be one produced by cytoplasmic inheritance. After selecting against genes which have a modifying effect, the inheritance of this type of male sterility follows the simple rules of maternal inheritance. By successive backcrossing the male sterile equivalent of most varieties and of most inbred lines can be established. This cytoplasmically-inherited male sterility produces emasculation of flowers on a grand scale. If the male parent has been selected against the modifying genes, whole populations of infinite size may be completely male sterile. In the work with curly-top-resistant varieties the male sterile equivalents of some of the best strains have now been established, but any thought of commercial utilization will depend upon further research, especially with breeding methods.

The knowledge of past success in breeding work adds confidence, but it is still difficult to look into the future and predict what may be done to establish a desirable character that appears to be practically non-existent. This is the present situation in this country with regard to prospects of developing unilocular biotypes of beets with single-germed seed balls. All of the present commercial varieties of sugar beets bear multilocular or multiple-germed seed balls, and this adds greatly to the task of thinning. The new and popular technique of shearing or splitting the seed balls into single-seeded portions, represents an artificial approach to the problem. It would seem that this artificial method should be considered only as a temporary answer, and the sheared or segmented seed might best be regarded as a victory model.

The problem of selecting for single-germed beet seed was popularized in this country a generation ago, but the work met with discouragement and was discontinued. A report of Russian work published in 1941 (2) seems to be the most encouraging news and indicates highly significant progress, as follows:

> "In the U.S.S.R., breeding work for the production of unilocular or single-germ varieties was originated by the Glav-Sakhar Breeding Station. In 1934 examinations were made in a large number of sugar beet seed fields and individual plants were selected from these in which all or most of the seed balls were unilocular. The seeds collected from such plants constituted the original material used in our work. The character for single-germ seed is under ordinary conditions recessive. In the F_2 generation, the plants segregate into types with unilocular and multilocular seed balls. The unilocular types were characterized by vigorous vegetative development and a peculiar type of seed bush. [Data are given showing a strong but not complete correlation between the unilocular character and an extreme non-bolting tendency.] While the number of seeds in a seed ball is found to vary greatly in ordinary beet varieties, depending upon environment, the new unilocular varieties are very constant. We were not able to change the number of flowers in the unilocular types of plants although we varied our dates of planting, nutrition, environment (both outdoor planting and greenhouse). We have thus produced lines of sugar beets which are constant for the character of single-germ seed."

In searching for biotypes with unilocular seed balls, the hope of utilizing the wild beet, B. *maritima*, may not be promising because so far as is known it produces multilocular seed balls, the same as those of the domesticated beet varieties. However, unilocular seed balls are produced by other wild species. *B. lomatogona* produces unilocular seed balls and it has been hybridized with sugar beets. The F_1 offspring have been strongly sterile, but hope from this work should not be abandoned. If other methods fail in the search for unilocular types of beets, extensive X-ray work could well be afforded to increase the possibility of a mutation that might be utilized.

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