TABLE BEET BREEDING

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Beta vulgaris includes cross-fertile cultivars of sugar beets, table beets, and swiss chard. All are herbaceous biennial diploids in the family Chenopodiaceae with a somatic chromosome number of eighteen. The vegetative cycle which occurs during the first growing season can be changed to a reproductive cycle by altering the thermo-photoperiod. Long days and cool temperatures will induce the reproductive cycle.

The mature inflorescence, which develops from the crown of the plant, is composed of large paniculate, more or less open, spikes. Flowers are borne singly in the axil of a large bract and may be accompanied by other lateral flowers formed in adjacent lateral bracts. Each flower has but a single ovule. A multiple fruit (multigerm) is formed by the cohesion of two or more flowers grown together at their bases and forming a hard, irregular, dry body, the so-called "seed ball". If the flower develops in the axil of the bract without any adjacent lateral flowers, a "single germ" seed (monogerm) will develop.

The beet flower is protandrous and is chiefly wind-pollinated. Large amounts of pollen are produced and can be blown for great distances. Controlled pollination can be made using paper bags although any opening of the bag for manipulations of any kind is almost certain to cause some contamination from pollen carried in the air currents surrounding the working area. Aphids can be a problem within the paper bags. Inserting ladybird beetles into the bag will aid in controlling aphids materially when other control measures fail.

Pollen sterility is known in beets. Genetic (recessive) and cytoplasmic-genetic types are known. Both are useful in a breeding program. Cytoplasmic pollen sterility can be used commercially for the production of F_1 hybrid seed in the manner originally suggested by H. A. Jones and A. E. Clarke for onions and later by F. V. Owen for sugar beets. According to Owen the genotype of the pollen-sterile plant is Sxxzz. There is some question concerning the accuracy of this deduction and Owen indicated shortly before his death that SxxZZ was a more probable genotype for the pollen-sterile plant. Our own work suggests Sxx as the genotype of the sterile. In the presence of the dominant gene X, other genes may change the plant to a partially fertile phenotype. This suggests that treating the material as a single gene effect (xx) is practical. Thus far four maintainer lines (Nxx) have been isolated and confirmed. These are in the S_6 generation. These are designated as W32, W162, W163 and W187. Many others are being uncovered now that the genetics of cytoplasmic sterility has been clarified in our material. The cytoplasmic sterility used in our program has been transferred from sugar beets to table beets by repeated backcrossed to pigmented types.

The use of gene steriles will be discussed later along with incompatibility.

The production of hybrid seed indicates a need for inbreeding in the potential maintainer stocks (normal cytoplasm). However, all table beet varieties tested thus far are self-incompatible. In order to facilitate inbreeding, a self-fertility (sf) allele of the s locus was obtained from Dr. V. F. Savitsky. The material was very poor from a horticultural viewpoint; consequently, the four maintainer inbreds listed earlier are only fair for horticultural type. The sf allele has allowed the effective self-pollination of many plants on a continuous basis up through the S_7 generation.

Inbreeding depression is not as great in table beets as expected. The sf allele renders a plant better than 99 per cent self-pollinated, with or without isolation, due to the large mass of pollen covering each pistil in every flower. In order to insure sib-matings in increase blocks of inbred table beets carrying the sf allele, a gene for male sterility (ms ms) is being introduced into inbred lines. Thus inbred ~~segregates of the genotype Nmsms must accept pollen from plants.~~

Another gene of considerable value obtained from Dr. V.F. Savitsky is the gene B for annual flowering habit. Commercial table beets are biennial (bb). Beets of genotype Bb planted in Madison, Wisconsin in mid-June are in full bloom by August 25. In our program all seed production and breeding work is done in greenhouse space which necessarily is limited. Therefore, it has been extremely useful to have annual cytoplasmically pollen sterile beets to use in the development of pollen-sterile inbreds. For example, a cross of genotypes SxxsfsfBb x N__sf_bb will give progeny from the male-sterile seed parent of which 50% are annual (Bb) and can be classified for pollen sterility under field conditions. Thus the genotype of the pollinator can be determined on sizable progeny without hindering our greenhouse program. After flowering, the pollen sterile annual plants are decapitated and reflowered in the greenhouse later thus allowing the continuous inbreeding of the S cytoplasm line concurrently with the maintainer line while continuously checking the genotype of the maintainer line. It follows that any time that biennial plants with S cytoplasm are desired for test crosses or commercial use that 50% of the population from the male-sterile seed parent will be biennial and can be used accordingly.

Another gene of considerable economic potential is the gene m which when homozygous (mm) gives rise to phenotypes with only one flower in the axils of the bracts, thereby producing "seed balls" with only one seed. Since this character can be screened in segregating material prior to making a controlled pollination, monogerm seed is readily fixed in breeding populations. In addition, it appears that the heterozygous Mm plants can be detected from homozygous MM plants by the number of flowers at each bract which is of value in breeding also.

Other genes which are less well-known are important horticulturally. Shape, color, type of crown and type of taproot development all respond to selection in inbreeding populations. Of these, only the genes controlling anthocyanin production are very well-known. According to the literature production of anthocyanin anywhere in the plant is determined by the R locus. In the presence of the alleles R and R^t, anthocyanin is produced - with R the amount of pigment is greater and extends into more organs than with R^t. When the r allele is present in the homozygous state no anthocyanin is formed, but a yellowish pigment is produced instead. At the locus Y, intensity and distribution of pigment are controlled - the Y alleles effect both the red and the yellow pigments in the same manner. In the presence of Y, coloration is intense, and the pigment is distributed uniformly throughout the plant, subject to local physiological modifications. These may be of quite large scope, but differently colored areas gradually blend into each other and they do not form sharply delimited spots. The allele Y^r restricts the pigment to the subterranean plant parts - root and hypocotyl of the mature plant. In y plants, pigment is very dilute, and is restricted to the hypocotyl ("shoulder" of the beet) and the base of rosette leaves. The loci R and Y are rather closely linked, with a crossover value of 7.5 - 8.0 percent.

In addition to these basic color genes, several pattern genes have been reported. These control distribution of either red or yellow pigments to specific sites in the foliage. The following genes belong to this group:

1) Cv - colored leaf veins.

2) T_r - "trout" or fine spot.

3) C_l - colored leaf; pigment concentrated in large blotches, sometimes covering as much as half a leaf.

The effect of these genes can be observed only in the absence of the solid color gene, i.e. the pattern genes are hypostatic to Y.

At the present time inbreeding table beets and the subsequent development of F_1 hybrids are practical. An area of need exists however in understanding the biochemical genetics of anthocyanin synthesis. Among the many red beet inbreds presumably homozygous for the favorable color genes listed above are types which include specific pigments ranging from lavender and blue through pink, orange and brown.