

Breeding Sugar Beets With Root Conformation Adapted to Machine Harvest¹

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THE VARIETIES of sugar beet as now grown are all characterized by having more or less elongated, obconical roots. Although soil and growing conditions may modify root shape to some extent, long parsnip-shaped roots that gradually taper to a point are the rule. A much shorter and more or less globe or top-shaped root would be easier to loosen and lift from the ground and could, therefore, be handled more efficiently by sugar beet harvesting machines. In addition, losses by breakage of the roots in the harvest operation and in the subsequent delivery of the beets to the sugar factory would be reduced.

Late in the 1947 harvest season hybrid beets with predominantly short, thick roots were given a trial run at Fort Collins, Colorado, with a harvester which tops the beets after lifting. Those who witnessed this trial were very favorably impressed by the efficiency of the harvester in handling these globose rooted sugar beets. Very few individuals were lost from the machine and there was practically no root breakage.

It is known that Achard's original "Runkelrüben," from which the sugar beet has been derived, consisted of an exceedingly variable mixture of types. The sucrose percentage of the roots, in comparison with modern sugar beets, varied from very low to mediocre. Achard noted three distinct root shapes in these beets: round, nearly apple-shaped roots; short, large crowned, radish- or pear-shaped roots; and long, spindle-shaped beets, gradually coming to a point. The general growth habit of the last class resembled that of our modern, long mangel-wurzels. However, it was in these long rooted types that Achard found the individuals that he believed contained the most extractable sugar. The White Silesian variety was obtained from Achard's selections.

Breeding of sugar beets has served to concentrate certain factors that were present in the White Silesian beet and has produced a beet of long, obconic shape, white in color and with a sugar content probably double that of the best individuals of the progenitor. Since high sugar content has always been the first concern of sugar beet breeders we might assume that the white color and conical shape of our sugar beets are characters that are linked with high sucrose content. Data from a selection project at

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Fort Collins indicate that the factors responsible for white color and high sugar content are linked, at least to some degree. For example, continued selections in a sugar beet x red garden beet hybrid were made on the basis of sucrose percentages and root weights, all other characters being disregarded. The F_2 of this hybrid contained approximately 75 percent of red roots. In the fourth generation of the line selected on the basis of high sugars and high root weights approximately 40 percent of the roots were red. In the sister line selected for low sugars and high root weights, approximately 90 percent of the fourth generation were red beets. Thus, it appears that there is a sound genetic reason for the white color of sugar beets.

The writer has observed little, if any, evidence that there is a similar linkage of the factors determining cone shape of root and high sucrose percentage. Hence, there is probably no genetic bar to the development of a short, more or less globe- or top-shaped beet that could be more efficiently handled by machinery than the present type of sugar beet root. The problem thus becomes one of finding suitable parent material from which the plant breeder may produce a sugar beet of the desired conformation. There are two main sources from which such parent material may be drawn. The more obvious of these sources is among the non-sugar varieties of beets, such as the more or less flattened or globe-shaped varieties of the red garden beet. The other source is from our present varieties of sugar beets. The factors for high sugar content, undoubtedly, must come from the latter source and it is probable that factors for short-root shape may also be found in our sugar beet varieties.

Since the trial run of the harvester at Fort Collins was made on a variety originating from a sugar x red garden beet hybrid, the possibilities of this cross will be considered first. This variety was the F_4 of a cross of U.S. 200 x 216 and a more or less globe-shaped red garden beet (variety unknown). White roots with better-than-average sugar content were selected from the F_2 of this hybrid. From the progeny, roots were again selected in the same manner to produce the seed from which the current (F_4) was grown. In spite of the fact that no attention was paid to root shape in these two selections, the F_4 of this hybrid had roots that were predominantly more or less globe- to top-shaped. There were also present in this crop a few beets that were either of long, obconic shape like the sugar beet or of typical globe shape like the red garden beet.

In 1947, at the experimental field on the Larimer County, Colorado, Hospital Farm, the buffer areas, in which are planted the overhead sprinkler lines, were planted with this hybrid. The buffer space accommodated 3 rows about 250 feet long. Thus, the hybrid beet occurred at about 60-foot intervals as strips across the experimental field. One of these buffer areas was between the second and third replications of the 8-variety, agronomic evaluation test of leafspot resistant varieties. The 3-row strip of the hybrid was harvested for comparison with the evaluation test. The sucrose percentage of the hybrid was 12.52 and the calculated acre yields were 18.17 tons of

roots and 4,547 pounds of gross sugar. In comparison, the general means of the whole agronomic evaluation test were 13.90 percent sucrose, with acre yields of 14.26 tons of roots and 3,967 pounds of gross sugar. Since several of the 8 varieties in the evaluation test produced in excess of 4,000 pounds gross sugar per acre, the yield of the hybrid may not be significantly above that of conventional sugar beet varieties, but the hybrid was undoubtedly as good as any of the conventional varieties in this test. However, the low sucrose percentage of the hybrid is a serious disadvantage.

In general, the performance of the hybrid was in agreement with the yields obtained from the F_3 of this hybrid and from F_3 to F_7 generations of a similar hybrid that has been in many tests since 1936. Briefly, during this period the sugar x red garden beet hybrid varieties have usually surpassed the standard sugar beet check variety in root yields, frequently by highly significant margins. However, due to consistently lower sucrose percentage of the hybrid, yield of gross sugar has exceeded that of the sugar beet check in only slightly more than one-third of 70 comparisons that were made. Instances in which the yield of gross sugar from either the hybrid or the sugar beet check variety has significantly exceeded the yield of the other have been rare.

Since the desirability of a beet with predominantly short roots was not foreseen this character had been disregarded in the selections made to date in the sugar beet-garden beet hybrids. However, even in the case of the hybrid carried to the F_7 by continued selections, the roots of the seventh generation are predominantly shorter and thicker than those of conventional sugar beet varieties.

It is probable that a number of genetic factors determine root shape in beets. Observation of inbred lines of hybrid origin indicates that the characters for true flat- or globe-shape may be simple recessive factors, readily manipulated by the plant breeder. On basis of work done to date, it should not be difficult to obtain a hybrid variety with white flesh and globose roots that would equal or exceed our present sugar beet varieties in root yield.

There remains the matter of sucrose content of the hypothetical sugar x red garden beet hybrid. To date, the best that can be said for the hybrids is that they have not been definitely unsuitable for sugar production. Occasionally in some test a hybrid line has been equal in sucrose percentage to a yield type of sugar beet included as the check variety. In general the hybrids have had a sucrose percentage that was from one-half point to as much as two points less than that of the sugar beet check variety. This relationship has held rather consistently throughout a fairly wide range of comparative tests.

Selection for sucrose content after the F_3 in these hybrids has maintained, or, at best, only slightly increased the gain secured by careful selection in the F_2 . On the basis of a single test, random increase of one of these hybrids from the F_3 to the F_6 resulted in no change in the sucrose

percentage and a small, statistically non-significant reduction in root yield. From the evidence at hand it is doubtful if selection alone in a sugar beet-garden beet hybrid will produce a hybrid variety that is fully satisfactory as to sugar content. Apparently backcrossing to a high-sugar sugar beet variety with rigid selection in the backcross generations for root yield and root shape is indicated.

It has been observed that these hybrid varieties are much more subject to a physiologic cracking of the roots and to attack by bacterial pocket (*Pseudo-monas beticola*) than the sugar beet varieties with which they have been grown. The 1947 crop of one of the lines of the selection project previously mentioned had over 20 percent of roots showing from a trace to severe cracking. Certain of lines have also produced crops with relatively high percentages of the roots having galls or over-growths particularly on or near the crown. This is a matter that will need attention.

The breeding investigations with these varieties show that selections for the customary economic characters have resulted in varieties that are predominantly globe- to top-shape. Root yields of the varieties have been high. Sucrose percentages usually have been so much below those of commercial varieties of sugar beet as to nullify any effects from the high root yields. In other words, gross sugar yields were, at best, about equal to the yields of standard varieties. Hence the varieties now available from hybridizing sugar and red garden beets; although superior for machine harvest, may not displace conventional sugar beet varieties. In some more northern districts where obtaining high root yields is the principal problem, these varieties may find acceptance. There is need for additional trials on a large scale of the globe- or top-shaped types to appraise the advantages in machine harvest as against other considerations. There is, of course, immediate need for improvement of the varieties without sacrifice of the desired root shape.

Discussion

The possibilities of obtaining a sugar beet variety with root conformation suitable for machine harvest from our present sugar beet varieties should be thoroughly explored. In the early stages of a selection program, mass selection can be very useful in quickly concentrating enough of the desired character in a variety that can be used while the ideal variety is sought by more detailed methods.

The inbred lines of sugar beets now in existence should be re-evaluated as to the shapes of their roots. New sources of genes for root shape should be tapped to obtain strains improved in root shape. It is unlikely that all the factors responsible for the apple-, radish- and pear-shaped roots noted by Achard in the progenitors of the White Silesian beet have been entirely lost from sugar beet stocks.

Seemingly unpromising possibilities should not be neglected. An example is a recessive abnormality tentatively called "celeriac root" that appeared in an inbred beet line at Fort Collins. This beet consists of little

more than a greatly over-developed crown with a relatively small amount of gnarled root tissue, the whole growing practically on the surface of the ground. This utterly worthless beet when crossed with normal sugar beets produced an excellent F_1 having roots of ideal shape for machine harvest. In the F_2 approximately one-fourth of the roots were of the celeriac parent type and the remainder were predominantly more or less similar to the F_1 roots. When this cross was grown a number of years ago no further selections were made. However, it is entirely possible that an excellent short-rooted beet variety could be obtained from this cross.

Summary

Short, globe- or top-shaped sugar beet roots appear to offer distinct advantages in the mechanization of sugar beet harvest. Varieties approximately equal to sugar beet varieties in gross sugar production and having the desired shape have been obtained by selection from the hybrids between sugar and red garden beets. In general, superiority of the hybrid variety in root weight is nullified by lower sucrose percentage. Additional appraisals are necessary to determine if the advantages with respect to harvesting are enough to over-balance the lower root quality. Breeding to improve the quality of the sugar x red garden beet hybrid is continuing. If the hybrid itself is not susceptible to improvement it may constitute an improved gene source. Although the factors responsible for short, globose root shape are certainly in the minority in present-day varieties, it is unlikely that they have been completely eliminated. Plant breeders should make an intensive search for these factors.