A Method of Selecting Individual Sugarbeet Roots for Weight and Sucrose Percentage[1]

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The selection of individual roots (so-called "mother beets") for weight and sucrose percentage, simultaneously, is a common practice in sugarbeet breeding. Powers (1)[3] has described a method of identifying mother beets genetically superior in both weight and sucrose. This method involves large populations of analyzed individuals. Quite frequently the breeder wishes to select from populations that are too small for the application of that technique. This article pertains to a method, applicable to populations of various sizes, which has been used with minor modifications in the disease resistance breeding program at Fort Collins, Colorado, for the past 10 years.

Where outstanding individuals are to be selected from a population of analyzed mother beets, the breeder frequently sets tentative minimum weight and sucrose percentage limits. Individual beets exceeding both these minimum standards are chosen. However, since weight and sucrose percentage tend to be negatively correlated, and for other reasons, the breeder may wish to make some allowance for especially high weight or especially high sucrose. For example, a beet that falls only slightly below the minimum standard for sucrose percentage may be considered desirable because of high weight. Conversely, an individual that is a little below the minimum standard for weight may be considered desirable because of high sucrose percentage. The use of gross sucrose per beet (i.e. weight $\times$ sucrose percentage) as the sole criterion for selection is unsatisfactory since, in actual practice, it tends to result in the selection of the largest individuals, giving too little "weight" to sucrose percentage.

If the weights and sucrose percentages of a group of comparable beets are plotted on a bivariate graph, a curve can be constructed to encompass the individuals to be selected. This curve can be so shaped as to give any desired weighting to each of the

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[3] Numbers in parentheses refer to Literature Cited.

two variables at any given point. This procedure can be simulated, with much less time and expense, by the following steps: (a) adjust the weight and sucrose percentage for each beet in any given group to conform to predetermined means; (b) compute a root (e.g. square root, cube root, fourth root, etc.) of the adjusted weight; (c) compute the adjusted gross sucrose (AGS)—i.e. (root of the adjusted weight $\times$ adjusted sucrose percentage) $\div$ 100; (d) rank the individual beets in descending order of the AGS values; and (e) choose the individuals ranking highest. After comparing curves simulated by this procedure, I decided to use the fourth root in step "b". Some breeders might prefer other mathematical roots. For example, if the cube root were used, the simulated curve would have less curvature, and use of the fifth root would result in greater curvature.

Adjustment of weights to conform to a predetermined mean is desirable for two reasons. First, if there are two or more groups of mother beets of any one genetic population, they will be made comparable for selection purposes; and second, the majority of the beets can be made to fall in an area where the simulated curve has a satisfactory slope. The first of these two reasons also is applicable to the adjustment of sucrose percentages.

Application of the Method

Table 1 shows the application of this technique to a group of 22 comparable beets of a rather heterogeneous, self-fertile, monogerm population. The plants were grown under severe *Cescospora* leaf spot exposure on the Hospital Farm at Fort Collins, Colorado, in 1966 with approximately 10-inch spacing in 20-inch rows. They were selected for resistance to leaf spot, with some attention to size and conformation, within a relatively small area of the field, and all were competitive with respect to spacing. Other plants of this population, selected from a contiguous area in the field, were considered as belonging to a different group and are not included in this report.

As may be noted in Table 1, the beets were weighed in kilograms and their respective weights were adjusted to conform to a mean of 2.50 kg. Sucrose percentages were adjusted to conform to a mean of 15.00. The adjusted weights and adjusted sucrose percentages are shown graphically in Figure 1. If the beets had been weighed in pounds, the weights would have been adjusted in the same manner, resulting in a mean of 2.50 lb. Thus the word, "weight", as used on the graph, is applicable to any scale of weights, and for this reason designation of the weight basis has been omitted.

Table 1.—Weights, sucrose percentages, adjusted gross sucrose values and intermediate computation steps for a group of 22 mother beets grown at Fort Collins, Colorado, in 1966.

Beet no.	Weight		$\sqrt[4]{\text{Adj. wt.}}$	Sucrose		AGS	Rank
	Actual	Adjusted		Actual	Adjusted		
	kg	kg	kg	%	%	kg	
711-25	0.50	2.16	1.212	14.5	15.67	0.190	9
-26	1.10	4.74	1.476	11.8	12.76	0.188	10
-28	0.45	1.94	1.180	15.2	16.43	0.194	7
-29	0.55	2.37	1.241	12.7	13.73	0.170	13
-30	0.35	1.51	1.109	14.8	16.00	0.177	12
-31	0.50	2.16	1.212	14.5	15.67	0.190	9
-32	0.45	1.94	1.180	12.2	13.19	0.156	19
-33	0.60	2.59	1.268	13.5	14.59	0.185	11
-35	0.50	2.16	1.212	12.4	13.40	0.162	17
-36	0.35	1.51	1.109	14.8	16.00	0.177	12
-37	0.90	3.88	1.404	13.6	14.70	0.206	4
-38	0.50	2.16	1.212	12.2	13.19	0.160	18
-39	0.45	1.94	1.180	15.6	16.86	0.199	6
-40	0.95	4.09	1.422	13.5	14.59	0.207	3
-41	0.65	2.80	1.293	14.4	15.57	0.201	5
-42	0.50	2.16	1.212	13.5	14.59	0.177	12
-43	0.50	2.16	1.212	14.7	15.89	0.193	8
-44	1.10	4.74	1.476	15.1	16.32	0.241	1
-45	0.40	1.72	1.145	13.5	14.59	0.167	15
-48	0.60	2.59	1.268	15.4	16.65	0.211	2
-49	0.60	2.59	1.268	12.3	13.30	0.169	14
-50	0.25	1.08	1.019	15.0	16.22	0.165	16
Average	0.580	2.500		13.87	15.00	0.1857	

Computation methods:

For the entire group of 22 beets:

$$A_w = \frac{2.50}{\text{Actual average weight per beet}} = \frac{2.50}{0.580} = 4.310$$

$$A_s = \frac{15.00}{\text{Actual average \% sucrose}} = \frac{15.00}{13.87} = 1.081$$

For any one beet:

$$\text{Adjusted weight} = \text{Actual weight} \times A_w$$

$$\text{Adjusted \% sucrose} = \text{Actual \% sucrose} \times A_s$$

$$\text{AGS} = \frac{\sqrt[4]{\text{Adjusted weight} \times \text{adjusted \% sucrose}}}{100}$$

The two curves in Figure 1 represent AGS values of 0.200 and 0.210, respectively. Beets ranking 1 and 2 in AGS values occur above the upper curve—i.e. they have AGS values higher than 0.210. Likewise, individuals ranking 1, 2, 3, 4 and 5, having AGS values higher than 0.200, occur above the lower curve. Just where the breeder would draw the imaginary AGS curve between the beets to be selected and those to be discarded would

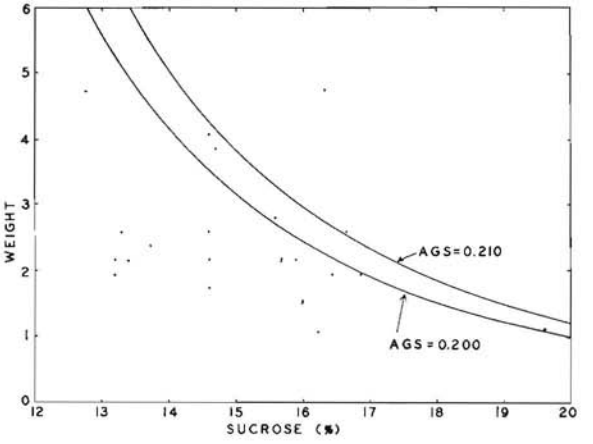

Figure 1.—Adjusted weights and adjusted sucrose percentages, for the 22 mother beets listed in Table 1, and adjusted gross sucrose curves for AGS = 0.200 and AGS = 0.210. Definition of weight unit is omitted since it is immaterial.

depend upon the number of beets available and the degree of selection pressure to be applied. In any case it should be noted that, in actual practice, there is no need to put the data in graph form. It is necessary, only, to construct a table, such as Table 1, and then select individuals on the basis of rank. If there are two or more groups of a given population, the AGS values also should be observed, or it may be more convenient to put the AGS values of all beets of all the groups of that population into a single list in the order of rank.

As may be observed in Figure 1 and Table 1, none of the adjusted weights were above 5.00 or below 1.00. The choice of 2.50 as the basis for the adjustment of weights has no special significance. However, if the basis for adjustment had been so low as to cause many of the adjusted weights to fall below 1.00, this would have been undesirable because AGS curves tend to be too nearly horizontal for weights below 1.00. Likewise, if the adjustment basis had been so high as to cause many of the adjusted weights to be above 6.00 or 7.00, this, also, would have been undesirable because, in my opinion, AGS curves in that region tend to be too nearly verticle. As a rule of thumb, I believe it is advisable to adjust weights in such a manner as to largely avoid adjusted weights below 1.00 or higher than 6.00 or 7.00.

Since the adjustment of sucrose percentages is desirable merely for the purpose of placing different groups of beets of a given genetic population on a comparable basis, the choice of a mean of 15.00 for adjustment purposes (Table 1) was an arbitrary one.

The choice of 14.00 or 16.00, for example, would have given the same results insofar as AGS rank is concerned.

The selection of the fourth root, in preference to other roots, for computation of AGS values, was merely a compromise between simulated curves of greater or lesser curvature. Actual research on the effectiveness of the method described in this article, with special emphasis on the use of other than the fourth root, would be desirable. At this point, the only advantages claimed for this technique are that: (A) it adds mathematical precision to a type of selection process that sugarbeet breeders frequently employ on a personal-judgment basis; and (B) it facilitates the delegation of selection duties to subordinates, thus freeing the breeder of much of the routine work involved. Presumably computerization of the mathematical procedures could be used to enhance the convenience of the method.

Summary

A mathematical technique has been devised by which individually analyzed mother beets may be selected with a curvilinear relationship between weight and sucrose percentage.

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Literature Cited

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