General Combining Ability of Sugar Beet Inbreds as Determined with Two Different Top Cross Testers

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An economical method for the production of hybrid seed tor testing general combining ability is needed if a multiplicity of sugar beet inbred lines are to be tested. The cost of converting all inbred lines to cytoplasmic male sterile equivalents or providing an isolation plot for each inbred for the production of hybrid seed would be prohibitive and would result in a serious limitation on the number of lines tested.

Investigation has shown that the ranking of inbred lines of corn for general combining ability can best be accomplished through the use of tester stocks which have a broad genetic base (3) (5)[2].

For sugar beet inbreds, a top cross tester variety having a dominant characteristic which would easily identify hybrid seedlings could be used for self sterile inbred lines (7). Deming (1) obtained significant differences between top cross progeny as to tonnage and total sugar using a red beet tester. Red garden beets have a dominant marker but a question has arisen as to whether the variety would be a reliable top cross tester inasmuch as the leaves are heavily pigmented and the yield of roots and sugar content are very low as compared to sugar beets. To resolve this question, the study reported here was devised whereby the top cross performance of inbreds using a red beet half sugar variety as a tester was compared with the top cross performance of the same inbreds using a commercial sugar beet variety as a tester.

In conjunction with the top cross testing some information was obtained as to the relationship of inbred performance to top cross performance.

Materials -and Methods

A group of inbred lines with green hypocotyl from the 1951 Inbred Performance test (8) was tested for general combining ability utilizing a commercial sugar beet variety and a red beet variety as the tester parents. The red beet variety, originally acquired from Germany, was unique because it could be considered a half-sugar type and because of the similarity of its root shape to the sugar beet. Roots of the sugar beet tester were red hypocotyl so that hybrids with the green hypocotyl inbreds could be identified, red being dominant over green.

A separate isolation plot was used for each tester parent. Roots from the green hypocotyl inbred lines were planted in both plots in alternate rows with roots of the top cross testers. The isolation plot for the red beet tester contained roots from red hypocotyl lines also. Seed was harvested from the inbreds by line.

The percentage of seedlings bearing the marker characters was calculated at the time germination percentages of the top cross seed lots were determined. A great diversity between lots as to percentage of identifiable hybrids was found due in part to different flowering dates and *in* part,

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[2] Numbers in parentheses refer to literature cited.

no doubt, to different degrees of self fertility existing between inbred lines. This diversity of hybrid percentages was also observed by Deming (1).

Planting rates were adjusted so that at least six hybrid germs were planted per foot of row. The design of the test was a triple lattice having 64 entries and six replications. The two test parents were included as entries. The individual plots consisted of six rows 22 inches in width and were 23.3 feet long. The plots were thinned to known hybrids as indicated by red hypocotyl for entries having a commercial top cross parent and red leaves for entries with a red beet parent.

At harvest the plots were trimmed to competitive beets. Six rows per plot, not exceeding 18 feet in length, were harvested for weight determinations with beets from two of these rows being analyzed for sugar percentage.

Seedling disease, following a dashing rain and hail, took a heavy toll in the plots. A near minimum number of hybrid seedlings coupled with the seedling disease resulted in the stands of some plots being reduced below a figure necessary for reliability of results. Following the calculation of the analysis of variance, those entries in which the harvested stand fell below 50 percent were disregarded for the calculation of the correlation coefficient.

The association of the results from the use of the two top cross parents for determining general combining ability was expressed as a correlation coefficient. There were reliable data for only 16 comparisons.

Correlation coefficients were also calculated to determine the association of combining ability as measured by the red beet tester with inbred performance records for the 31 inbreds used in this comparison were taken from the Longmont test of the 1951 fnbred Performance Test (8).

Correlation coefficients were calculated for total sugar and its components, tonnage and sugar percentage.

Discussion of Results

A comparison of the use of a red beet tester parents and a commercial tester parent for measuring general combining ability is summarized in Table 1.

Table 1.—Association of Top Cross Performance of Sugar Beet Inbreds Using a Sugar Beet Tester with Top Cross Performance Using a Red Beet Tester for 16 Comparisons.

	Tons per Acre	Sugar Percentage	Pounds Sugar per Acre
Sugar Beet	21.4	13.2	5,629
Red Beet	20.6	10.7	4 367
C.V.[1]	8.23	5.76	10.05
r	.67[2]	.79[3]	.52[3]

[1] Coefficient of variability of the whole test from which the comparisons were extracted.
[2] Significant at the 5 percent level of probability.
[3] Significant at the 1 percent level of probability.

The correlations, r = .67 for tons per acre and r = .79 for sugar percentage are slightly but significantly higher than the correlation, r = .52, for their product, sugar per acre. A correlation coefficient of .47 is necessary for significance at the 5 percent level of probability and .59 for the 1 percent level of probability. Errors for both tonnage and sugar content are confounded in total sugar and would be expected to be reflected in the correlation coefficient.

More confidence could be placed in these results if the rank association as measured by the correlation coefficient was higher and the number of comparisons was greater. The results do indicate, however, that rather satisfactory predictions could be made using either of the two top cross testers.

Both tester varieties have a broad genetic base; however, the base for each of the two varieties is quite different. Because of this difference in genetic base, some expression of combining ability specific for the two varieties would not be unexpected. However, with the limited number of comparisons available for analysis it would probably not be possible to demonstrate a significant tester by line interaction.

The reliability of one tester over another for measuring general combining ability of sugar beet inbreds will be determined only after specific hybrids of inbreds have been tested. Perhaps the use of several testers will be required for efficient evaluation of inbreds for combining ability. Inasmuch as the red beet as a top cross tester gives results reasonably comparable to a commercial variety used as a tester, the ease of manipulation warrants its use as a tester stock for determining general combining ability, particularly at this early stage of the inbred-hybrid program.

The correlation existing between top-cross and inbred performance was expected (Table 2) . For this comparison the red beet was used as the tester parent. The correlation, r = .37, is more than necessary for significance, at the 5 percent level, between tonnage of the top cross and the tonnage of the inbred and is similar in magnitude to the correlations for yield in corn inbreds and top crosses. The works of Nilsson-Leisnner (6) , Jorgenson and Brewbaker (4) and Jenkins (2) all showed an association between inbred yield and hybrid yield in corn. This association, however, was rather weak.

Table 2.—Association of Top Cross Performance Using the Red Beet Tester with Inbred Performance for 31 Comparisons.

	Tons per Acre	Sugar Percentage	Pounds Sugar per Acre
TC Red Beet	20.9	10.6	4,395
Inbred	18.3	16.7	6,097
TC Parent	18.5	6.9	2,335
Inbred, adjusted	17.0	13.7	4,670
C.V. %, T.C. test[1]	8.23	5.76	10.05
C.V. %, Inbred test[1]	13.15	3.14	13.52
r	.37[2]	.68[3]	.43[2]

[1] Coefficient of variability of the whole test from which the comparisons were extracted.
[2] Significant at the 5 percent level of probability.
[3] Significant at the 1 percent level of probability.

The correlation between the sugar percentages of the inbreds and the sugar percentage of their top cross progenies, r = 68, is more than necessary for significance at the 1 percent level. This correlation is high compared to the correlation existing for tonnage, r = .37. The close association between the sugar content of inbreds and their top cross progeny suggests that the genes which condition sugar percentage exhibit little or no dominance and are additive. By a rough comparison through the commercial check varieties in both tests the average sugar percentage of the

inbreds tested would have been 13.7 percent had they been included in the same test with the top cross hybrids. The average between this figure and the sugar percentage of the top cross parent (6.9 percent) is 10.3 percenter very close to the average sugar content of the top cross hybrids (10.6 percent) . If dominance exists it is probably negligible. The same type of observations have been made at this Station in connection with hybrids between high and low sugar content varieties, and have always resulted in an intermediate sugar content. Further evidence that dominance is not a primary characteristic of genes conditioning sugar percentage in sugar beets is the lack of depression in this character as inbreeding progresses.

The association of the total sugar produced by the inbreds and their top cross progeny, $r = .43$, which is more than necessary for significance, at the 5 percent level, reflects the low correlation for tonnage for the same comparison and to some extent the error attached to both the tonnage and sugar percentage figures.

In regard to selection of inbreds, the data from this test would indicate that relatively more is to be gained from selection for sugar percentage than for tonnage if it is assumed that inbreds will react in hybrids with other inbreds as they react in hybrids with varieties.

Additional information concerning combining ability will be available as the use of the top cross testing continues and as hybrids from inbreds are produced. Information as to the behavior of the various disease reactions and chemical characters relative to combining ability will greatly aid the development of inbred lines which will be of value in hybrids.

Sugar beet breeders as they approach the inbred-hybrid program are very fortunate in having at their disposal the large reservoir of information compiled by the corn breeders. Breeding problems in sugar beets will be more easily solved because of this information and the speed of improvement might well be greater than for corn.

Summary

1. The association of combining ability of 16 inbreds as measured by a commercial sugar beet variety tester and by a red beet tester was r = .67 for tonnage, $r = .79$ for sugar percentage and $r = .52$ for total sugar. These figures, which were statistically significant, were taken as evidence that the reliability of the red beet tester was sufficient to warrant its use, particularly when its ease of manipulation for making hybrids is considered.

2. The association of combining ability of 31 inbreds as measured by the red beet tester and the performance of the 31 inbreds was $r = .37$ for tonnage, r = .68 for sugar content and r = .42 for total sugar. These data indicate that the sugar percentage of the inbred will determine to a large extent the sugar percentage of the hybrids of which they are a component. The behavior of sugar percentage in hybrids would lead to the conclusion that genes conditioning sugar percentage are additive and exhibit little or no dominance.

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