Genetic Diversity in Sugarbeet Lines Selected for Nematode Resistance

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Most commercial sugarbeets grown in the United States today are three-way top cross hybrids; however, some single-cross hybrids and open-pollinated varieties are grown. One of the advantages of hybrids is the heterosis obtained by crossing different inbred lines.

The amount of heterosis shown in any particular cross depends, among other things, on the differences of gene frequency between the parent populations. This would indicate that the amount of heterosis would increase with the degree of genetic differentiation between the two populations (2).[2]

A number of studies have indicated that the degree of heterosis of a cross is in direct relation to genotypic differences of the parents (1,3,5,8). Hayes (6) states that genetic diversity is a basic principle of great value to the breeders of hybrid corn. Helmerick, et al. (7) tested five genetically different sugarbeet cultivars from U.S. Department of Agriculture and American Crystal Sugar Company sources. He found genetic diversity to be important in sugarbeet hybrids, and suggested the use of cultivars from different geographical areas to increase the genetic diversity.

Because of the need for disease resistance in sugarbeets grown in the United States, the potential sugarbeet gene pool has been narrowed. This has reduced the genetic diversity between inbred parents of commercial hybrid sugarbeets. A greater heterosis effect might be realized by incorporating disease resistant material of divergent origin into a breeding program. This study was initiated to evaluate this approach.

Materials and Methods

We studied a series of nematode selections collected from several breeding stations in both the United States and Europe. Several lines or selections from each source were mixed together and coded (Table 1). We divided the eight sources into two groups (A and B), and made all possible crosses between groups by alternately planting photothermally induced roots of each of

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[2] Numbers in parentheses refer to literature cited.

Table 1.—Description, code, and group assignment of parents.

Group	Code	Description and source
A	RRS1	Mixture of nematode selections from Charles Price (USDA)
A	RRS2	Mixture of nematode selections from G. J. Curtis (England)
A	RRS3	Broadbase synthetics (Great Western Sugar Co.)
A	RRS4	Mixture of introductions (Poland)
B	RRS5	Mixture of nematode-root rot selections (American Crystal Sugar Co.)
B	RRS6	Mixture of nematode selections from Clifton Smith (USDA)
B	RRS7	Mixture of nematode selections from H. Reitberg (The Netherlands)
B	RRS8	US H9B, virus yellows tolerant (USDA)

Table 2.—Mean root yield, percent sugar, and gross sugar for different sources of germ plasm (RRS numbers) and their respective crosses.

Entry	Root yield tons/acre	% sugar	Gross sugar lbs/acre
1 × 5	24.2	17.3	8,319
1 × 6	19.6	17.3	6,740
1 × 7	23.6	17.5	8,225
1 × 8	23.9	17.5	8,394
2 × 5	23.2	17.4	8,319
2 × 6	25.1	18.1	9,090
2 × 7	26.3	17.9	9,391
2 × 8	26.3	17.4	9,109
3 × 5	22.9	16.8	7,670
3 × 6	21.0	16.8	7,041
3 × 7	24.6	17.0	8,394
3 × 8	23.5	17.0	7,981
4 × 5	20.3	17.3	7,022
4 × 6	20.7	17.3	7,153
4 × 7	23.8	17.9	8,310
RRS1	23.1	17.0	7,811
RRS2	24.8	17.6	8,478
RRS3	22.1	16.4	7,229
RRS4	19.1	17.8	6,815
RRS5	21.7	17.3	7,520
RRS7	22.6	17.6	7,971
RRS8	27.1	17.2	9,325
LSD .05	2.6	.08	921

the two parents in each cross in an isolation plot. Plants were allowed to intercross and seed was harvested and bulked from all plants for each cross (Table 2). All lines were self-sterile except US H9B, which was largely male-sterile. In crosses involving US H9B, seed was harvested only from plants of US H9B.

All crosses and parents were planted in a replicated field trial in 1969 at the Salinas station. Plots were single 20-foot rows, replicated six times in a randomized block design. At harvest time data were taken on clean root weight and percent sucrose.

Data were analyzed for root yield, percent sugar, and gross sugar. The estimates of the variance components for general combining ability for group A, general combining ability for group B, and specific combining ability were calculated from the analysis of variance for the above three characters (9). The mean heterosis for each parent was computed as: 1) heterosis greater than the mid-parent, and 2) heterosis greater than the high parent. Cross 4 x 8 and parent RRS6 were not included in the trial because of lack of seed; therefore, the precision for estimates that involve these two missing entries is less than for the remaining entries.

Results

There were differences in root yield, percent sugar, and gross sugar between parents and between crosses (Table 2). RRS8 (US H9B) significantly outyielded all other parents; however, some crosses yielded equally as well. Parent RRS8 was a commercial hybrid, but the remaining parents were mixtures of heterozygous lines. Parent RRS3 was the lowest parent in percent sugar. Crosses having RRS3 as one parent were, likewise, low in percent sugar.

The variances for general combining ability were significant for both groups except percent sugar for group B (Table 3). This indicates that there were significant differences among members of each group for general combining abiltiy. A significant specific combining-ability variance was obtained for gross sugar but not for root yield or percent sugar.

Table 3.—Estimates of general and specific combining ability variances among parents for root weight, percent sugar, and gross sugar.

Character	General combining ability variance		Specific combining ability variance
	Group A	Group B	
Root weight (lbs)	13.46**	16.04**	—2.11
Percent sugar	3.264**	0.016	—0.023
Gross sugar (lbs)	0.64**	0.50**	0.40*

* = Significant at .05
** = Significant at .01

The mean heterosis estimates for each parent show large differences among parents (Table 4). RRS8 (US H9B) demonstrated the most negative heterosis, while RRS7 and RRS2 gave

Table 4.—Mean heterosis for root weight, percent sugar, and gross sugar for the eight sources of germ plasm computed as greater than the mid parent and greater than the high parent.

	Root wt (lb/plot)		% Sugar		Gross sugar (lb/plot)	
Parents	Mid parent	High parent	Mid parent	High parent	Mid parent	High parent
RRS1	—2.3	—4.4	0.7	0.2	—0.19	—0.33
RRS2	6.1	0.4	0.8*	0.6	2.57**	1.45**
RRS3	4.7	3.7	0.4	—0.7	0.97*	0.41
RRS4	10.1**	2.9	—0.5	—0.8*	1.19*	0.19
RRS5	5.7	0.5	0.2	—0.7	1.26**	0.53
RRS6		—9.3*		1.2*		—0.29
RRS7	12.1**	8.5*	0.5	—0.4	2.44**	1.69**
RRS8	—4.8	—16.4**	0.7	—0.1	—0.27	—2.35**
Total mean	2.8*	—1.7	0.5*	—0.1	0.95**	0.16

* = Significant heterosis at .05
** = Significant heterosis at .01

the greatest positive heterosis. Greater heterosis was observed for gross sugar than for root yield or percent sugar. The average mid-parent heterosis for all crosses was significantly greater than the parental average for root weight, percent sugar, and gross sugar.

Discussion

Differences in general combining ability are due to the additive, and additive times additive genetic variances in the base population; whereas differences in specific combining ability are attributable to the non-additive genetic variance.

"In the terminology of Falconer (2), the between-cross variance=
$F\ Va + F^2\ Vd + F^2\ Vaa + F^3\ Vad + F^4\ Vdd + \ldots$
where Va=additive variance
Vd=dominance variance
Vaa=additive times additive variance
Vad=addtiive times dominance variance
Vdd=dominance times dominance variance
F=coefficient of inbreeding."

As the coefficient of inbreeding is reduced, or as heterozygosity is increased, the non-additive portion of the between-cross variance becomes smaller. The parents in this study were highly heterozygous, which is probably the reason for the small estimates of specific combining ability variance.

A negative correlation between root weight and percent sugar has been reported (4,10). In earlier work, we found that within a uniform field trial, this negative correlation was largely genetic. In the present test some crosses showed less negative correlation between root weight and percent sugar than their parents, whereas other crosses exhibited larger negative correlations than their parents. These differences resulted in a significant specific combining-ability variance for total sugar (Table 3). Crosses involving parents RRS2, RRS5, and RRS7 tended to have less negative correlation between root yield and percent sugar than their respective parents, whereas crosses involving RRS1, RRS4, and RRS6 had greater negative correlation than their parents.

The amount of heterosis is dependent upon the amount of genetic diversity of members of group A to group B and vice versa. The pedigrees or relationships of the parents are unknown however, RRS1 of group A has a closer genetic relationship to RRS6 and RRS8 in group B than the other members of group A.

Parent RRS7 is more divergent genetically to members of group A than other members of group B. From these observations, it appears that the wider the genetic divergence, the greater the heterosis in the offspring.

When the nature of the crossing system is considered, the achieved heterosis becomes even more significant. Since all plants were self-sterile and each parent was highly heterozygous, there was considerable intercrossing within parents in each cross. Thus, each cross consisted of seed resulting from: 1) the cross of the two parents; 2) intercrossing within one parent: and 3) intercrossing within the other parent. Therefore, the portion of true crossed seed in each cross had sufficient heterosis to make the entire cross superior to its parents. Crosses involving RRS8 did not fall into this category. RRS8 was a hybrid; therefore, crosses with RRS8 were more like F_2's and were expected to demonstrate less heterosis than the hybrid parent.

These data indicate that genetic diversity is important in the production of hybrid sugarbeets, and that greater heterosis is made possible by introducing greater genetic diversity into future hybrids.

Summary

Significant general combining-ability variances among heterozygous populations were obtained for root yield, percent sugar, and gross sugar. A significant specific combining-ability variance was observed for gross sugar only.

There were significant differences in mean heterosis between these heterozygous populations. Those populations believed to be the most divergent genetically exhibited the most heterosis.

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