Combining Ability in Autotriploid Sugar Beets, *Beta vulgaris* L.

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Introduction

Twenty-eight years ago plant breeders were presented with a new and revolutionary breeding method (4,8)[2]. The discovery that polyploid strains of plants could be produced in large numbers through the action of the drug colchicine appeared to be a valuable plant breeding tool.

Shortly following this discovery European and North American sugar beet geneticists and plant breeders began to produce autotetraploid strains of sugar beets (1,12,13,14,15). They found that although these tetraploid sugar beets could be maintained at this high polyploid level, the yield of tetraploid beets was generally lower than the original diploid varieties (2,3). Several North American plant breeders (2,12,15) produced and tested limited quantities of triploid sugar beets. They concluded that there was little difference between the yield of the triploid hybrids and diploid varieties. Peto and Boyes (12) reported that the percentage of sugar did not decrease with increased size of root as rapidly in triploids as in diploid beets. Perhaps because of the difficulty in producing tetraploids or the failure of substantial success in polyploid beet breeding, further work on polyploid beets was terminated in North America.

Such was not the case in Europe where today many of the diploid varieties are being replaced by polyploid hybrids (7). The European sugar beet breeders believe that better combination of high sucrose with high tonnage can be obtained at the polyploid level than at the diploid level. They attribute the increase in yields to the triploid hybrids. Because male-sterile diploids were unavailable, most of the commercial polyploid hybrids now used in Europe are produced by planting tetraploid and diploid seed together in the same field. The percentage of triploids in the resulting commercial seed is controlled by unbalancing the parental populations. The commercial plantings are actually a mixture of tetraploid, triploid and diploid plants.

The experiments reported in this paper were designed to test the combining ability of pure triploid sugar beets produced with male-sterile diploid parents. The hybrid populations are

[1] Plant Breeder, Manager Research Station and Plant Breeder, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

[2] Numbers in parentheses refer to literature cited.

approximately 100 percent triploid except for an occasional diploid plant which occurred because of foreign pollen or roguing failures.

Materials and Methods

In 1960, the American Crystal Sugar Company received twenty multigerm strains of tetraploid sugar beets through a cooperative agreement with Kleinwanzlebener Saatzucht of Einbeck, Germany. These tetraploid populations are coded in this paper as 61-4T1 through 61-4T20 with 61-4T28 being the American tetraploid US 401(4n). Seven diploid male sterile monogerm populations were obtained from United States Department of Agriculture sources. Table 1 presents the code number and pedigree of these male steriles. Male steriles 2, an American Crystal increase and 8, a USDA increase, are believed to differ only by the seed source.

Table 1.—Code numbers and pedigrees of the seven diploid male-sterile lines used as the female parents to produce the triploids in this paper.

Code No.	Pedigree
2	SLC #129 MS (ACS 60-424)
3	C 9561-3HO
4	7-515 MS × 9561
5	F59-569HO
6	F59-507H1 (8-515 × 507 rr)
7	F59-507H2 (8-569HO × 8-507 rr)
8	SLC #129 MS (SLC 0166 rr mm MS)

Thermally induced stecklings of these tetraploid and diploid populations were obtained from Phoenix, Arizona, in the spring of 1961. The tetraploid and male-sterile populations were planted in twenty isolated groups at Canon City, Colorado. The groups were planted to permit each male-sterile parent to be bordered by the tetraploid pollinator, thus ensuring adequate available pollen. The male-sterile populations were rogued to male-sterile plants in order to help ensure the production of 100% triploid seed.

Each male-sterile population was harvested separately with the result that 140 triploid hybrids were obtained. However, sufficient triploid seed to complete a diallel series was obtained on 16 of the triploid isolations. The resulting 112 triploids were tested at Clarksburg, California; Rocky Ford, Colorado; and East Grand Forks, Minnesota. The experimental design at all locations was an 11 × 11 triple lattice repeated three times. The data included in this paper were extracted from the larger design and grouped as a randomized complete block experiment. Nine replications were used in the Colorado and Minnesota data while only six replications were used for the California data.

The data were analyzed using the component of variance method in Table 2. The variances associated with males and females were considered a measure of general combining ability, while the interaction of males × females was considered a measure of specific combining ability.

Table 2.—Analysis of variance, mean square expectations and variance components used to analyze the data for the three locations.

Source of variation	d.f.	Mean square	Parameters estimated	Variance components
Replications	(r-1)			
Test crosses	(c-1)			
Females	(f-1)	M_1	$\sigma^2 + r\,\sigma^2_{FM} + m\,\sigma^2_F$	$\sigma^2_f = M_1 - M_3/rm$
Males	(m-1)	M_2	$\sigma^2 + r\,\sigma^2_{FM} + fr\,\sigma^2_M$	$\sigma^2_m = M_2 - M_3/rf$
Females × males	(f-1) (m-1)	M_3	$\sigma^2 + r\,\sigma^2_{FM}$	$\sigma^2_{fm} = M_3 - M_4/r$
Error	(r-1) fm-1)	M_4		
Total	(rfm-1)			

Experimental Results

The combination analysis of variance for the three locations showed highly significant mean square values for all sources of variation involving locations, Table 3. This reaction was expected due to the wide environmental differences between growing areas. The mean square values for the interaction of males with locations were greater than the interaction of females with locations for both factors studied. Because of the magnitude of these interactions it was necessary to analyze and discuss each location separately.

Table 3.—Combined analysis of variance for the 112 triploid hybrids at three locations.

Source of variation	d.f.	Tons/Acre MS	Sucrose MS
Entry × location	222	19.06**	2.52**
♂ × location	30	47.64**	7.36**
♀ × location	12	23.88**	3.54**
♂ × ♀ × location	180	13.97**	1.64**

California Combining Ability Test

Highly significant differences existed between male and female entries indicating the presence of general combining ability for tons per acre and sucrose percent in the California data, Tables 4 and 5. The specific combining ability as measured by the female × male interaction was highly significant for tons per acre while specific combining ability for sucrose percent was non-existant. The variance components of both yield factors were considerably higher for males than females.

Table 4.—Analysis of variance and variance components for tons per acre at the three locations.

Source of variation	d.f.	California		Colorado		Minnesota	
		M.S.[1]	V.C.[2]	M.S.[1]	V.C.[2]	M.S.[1]	V.C.[2]
Females	6	31.99**	.091	455.92**	2.301	47.99*	.1771
Males	15	112.43**	2.122	985.52**	13.665	170.61**	2.351
Females × males	90	23.26**	2.110	124.61*	2.977	22.49	—.0233

[1] Mean square
[2] Variance components

Table 5.—Analysis of variance and variance components for sucrose percent at the three locations.

Source of variation	d.f.	California		Colorado		Minnesota	
		M.S.[1]	V.C.[2]	M.S.[1]	V.C.[2]	M.S.[1]	V.C.[2]
Females	6	7.85**	.0764	3.49**	.0019	2.793**	.0150
Males	15	14.52**	.3335	9.97**	.1071	2.082**	.0865
Females × males	90	0.52	—.0406	3.22**	.2451	0.632	.0090

[1] Mean square
[2] Variance components

Tables 6 and 7 present the California yield data. There is little statistical evidence that would indicate reliable differences between females crossed to the same male, however, the experiment may not have been precise enough to detect these differences. Statistical differences between males crossed to the same female were numerous for both yield factors. This would indicate a greater variation between the tetraploid types crossed with the same female than between male-sterile types crossed to the same male. Statistical differences are evident between certain male and female parents when averaged over all their appropriate testers.

Colorado Combining Ability Test

The analysis of variance and variance components for tons per acre and sucrose percent of the Colorado data are presented in Tables 4 and 5. Highly significant differences between males and between females are evident. The variance components for males are considerably higher than those for females for both factors. This reaction was also apparent in the California data. The interaction of females × males was significant at the 5 percent level for tons per acre and highly significant for sucrose percent.

The actual yields of the triploids at Rocky Ford are included in Tables 8 and 9. The general trend found in the California data continued. Greater variability is found between tetraploids crossed to the same female than between females crossed to the same male.

Table 6.—Tons per acre for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmis male-sterile types (California data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	23.22	20.34	19.99	20.47	19.48	23.74	19.41	20.95	NS	
2	18.40	22.12	20.06	18.79	16.89	17.43	16.73	18.63	3.24	
3	18.32	18.70	19.52	17.30	19.94	18.39	21.91	19.15	NS	
4	21.00	22.47	21.04	22.45	22.74	22.18	22.60	22.01	NS	
8	19.74	19.03	18.54	20.04	21.55	18.56	18.45	19.41	NS	
9	24.82	22.59	25.31	22.87	24.02	25.85	24.71	24.31	NS	
10	18.10	25.40	21.47	22.47	20.16	22.76	23.28	21.94	3.85	
11	17.89	20.73	20.86	18.81	17.71	19.14	18.10	19.03	NS	
13	22.28	25.02	22.96	24.48	22.35	23.50	23.28	23.41	NS	
14	20.45	22.48	17.75	20.77	21.01	24.03	18.03	20.64	NS	
15	19.30	24.37	22.86	21.30	23.41	25.64	23.79	22.95	NS	
16	22.69	19.71	22.08	18.89	22.46	20.20	19.44	20.78	NS	
17	19.69	22.98	21.14	20.10	19.13	20.42	17.44	20.12	NS	
19	18.58	21.30	21.89	21.78	22.82	23.50	21.31	21.59	NS	
20	22.08	22.61	21.36	22.41	21.18	22.45	19.20	21.64	NS	
28	19.43	20.49	21.84	20.65	20.73	18.77	19.43	20.19	NS	
Mean	20.38	21.90	21.17	20.85	20.98	21.66	20.42	21.04		
LSD (0.05)	2.43	3.97	NS	NS	NS	4.25	4.14			
LSD (0.01)	3.23	NS	NS	NS	NS	5.64	5.49			

Yield of commercial check = 18.38 tons per acre

LSD	Between male-sterile means	.05 = .92	.01 = 1.22
	Between tetraploid means	.05 = 1.39	.01 = 1.84
	Between triploid means	.05 = 3.69	.01 = 4.86

Table 7.—Sucrose percentages for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmic male-sterile types (California data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	12.97	12.65	12.64	12.68	12.72	13.30	13.46	12.91	NS	
2	13.01	12.16	12.28	12.38	12.93	13.28	12.16	12.60	NS	
3	12.67	12.49	12.28	12.31	13.08	12.68	12.93	12.63	NS	
4	13.89	13.19	13.40	13.11	13.90	14.19	13.83	13.64	NS	
8	13.60	13.62	13.19	13.38	14.19	14.21	14.38	13.79	NS	
9	13.49	13.25	13.12	13.27	13.47	13.34	13.05	13.28	NS	
10	12.14	11.57	12.34	12.04	12.63	12.18	12.54	12.20	NS	
11	12.66	12.52	11.82	12.17	12.45	12.79	13.03	12.49	NS	
13	13.36	11.75	11.92	12.78	12.84	12.94	13.05	12.66	.78	1.05
14	12.54	12.58	12.54	12.29	12.58	12.98	12.75	12.61	NS	
15	13.08	12.09	12.28	12.33	12.32	12.42	12.52	12.43	NS	
16	12.97	12.44	12.33	12.48	12.44	13.23	12.85	12.68	NS	
17	12.56	11.78	12.62	12.09	13.50	13.28	12.84	12.67	1.03	NS
19	13.44	13.02	13.03	12.70	13.54	13.62	12.99	13.19	NS	
20	13.29	11.91	12.28	12.18	12.44	12.94	13.16	12.60	NS	
28	11.16	11.08	10.75	11.58	11.36	11.71	11.16	11.26	NS	
Mean	12.93	12.38	12.43	12.49	12.90	13.07	12.92	12.73		
LSD (0.05)	1.09	1.03	.96	.96	1.05	.99	1.05			
LSD (0.01)	1.45	1.37	1.28	NS	1.39	1.32	1.40			

Yield of commercial check = 12.67 percent sucrose

LSD	Between male-sterile means	.05 = 0.25	.01 = 0.32
	Between tetraploid means	.05 = 0.37	.01 = 0.49
	Between triploid means	.05 = 0.99	.01 = 1.30

Table 8.—Tons per acre for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmic male-sterile types (Colorado data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	25.49	25.10	24.39	25.32	27.82	28.20	25.86	26.02	NS	
2	23.44	25.12	22.92	24.26	23.29	23.96	22.44	23.63	NS	
3	23.49	24.38	24.74	24.43	25.05	26.71	22.99	24.54	NS	
4	25.21	24.34	24.97	24.08	25.12	25.47	24.63	24.83	NS	
8	23.62	22.35	23.72	23.32	22.46	22.79	22.45	22.96	NS	
9	27.85	27.16	26.06	25.72	27.05	28.73	25.15	26.81	NS	
10	24.38	27.09	27.63	24.99	26.88	28.42	28.13	26.78	NS	
11	26.76	26.91	25.96	26.71	26.80	28.48	23.68	26.47	NS	
13	25.72	26.64	26.53	25.11	27.45	27.03	24.51	26.09	NS	
14	24.08	26.16	22.95	26.19	25.57	23.72	19.81	24.07	2.83	3.77
15	24.22	25.19	26.97	28.04	25.18	27.02	27.37.	26.28	NS	
16	23.18	25.51	25.05	21.81	24.98	24.25	24.14	24.13	NS	
17	25.35	27.44	26.45	24.07	28.64	26.58	24.65	26.11	2.98	NS
19	26.59	28.06	22.09	25.47	26.33	26.49	26.25	25.90	NS	
20	24.36	25.86	25.25	25.57	25.14	27.08	23.71	25.28	NS	
28	29.17	27.76	28.85	26.46	26.56	27.19	29.15	27.87	NS	
Mean	25.17	25.93	25.27	25.08	25.88	26.37	24.62	25.49		
LSD (0.05)	2.78	3.11	3.12	3.04	NS	3.33	3.10			
LSD (0.01)	3.68	NS	4.11	NS	NS	NS	4.09			

Yield of commercial check = 24.04 tons per acre

LSD			
LSD	Between male-sterile means	.05 = .77	.01 = 1.02
	Between tetraploid means	.05 = 1.77	.01 = 1.54
	Between triploid means	.05 = 3.10	.01 = 4.08

Table 9.—Sucrose percentage for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmic male-sterile types (Colorado data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	12.86	13.58	13.83	13.72	13.96	14.08	13.95	13.71	NS	
2	12.51	14.26	13.50	14.41	14.24	14.56	14.10	13.94	1.13	1.51
3	14.44	15.22	14.36	14.58	13.19	14.31	14.30	14.34	1.08	NS
4	14.42	13.54	14.18	13.88	14.10	14.33	14.69	14.16	NS	
8	14.23	14.91	13.82	13.88	14.60	14.82	14.82	14.44	NS	
9	14.34	13.65	14.32	13.76	13.90	14.30	14.24	14.07	NS	
10	14.58	14.18	12.98	14.21	14.56	13.88	14.44	14.12	NS	
11	14.74	14.32	15.12	14.62	14.48	14.73	14.71	14.67	NS	
13	14.05	14.03	14.09	14.50	13.39	14.16	13.99	14.03	NS	
14	14.14	14.33	14.12	14.05	14.24	14.62	13.72	14.18	NS	
15	14.03	13.89	12.67	13.63	13.70	13.78	13.35	13.58	NS	
16	13.72	14.03	13.53	13.79	13.90	14.94	13.19	13.87	NS	
17	11.50	12.90	12.83	13.28	12.98	13.26	13.88	12.94	1.16	1.54
19	13.73	13.51	13.73	13.61	13.50	13.85	14.12	13.72	NS	
20	14.20	13.78	14.25	14.15	14.18	13.82	15.35	14.25	.93	NS
28	14.05	13.90	13.94	13.85	14.04	14.39	14.00	14.02	NS	
Mean	13.84	13.99	13.82	13.99	13.93	14.23	14.17	14.00		
LSD (0.05)	1.09	1.15	1.11	NS	NS	NS	1.02			
LSD (0.01)	1.44	NS	1.46	NS	NS	NS	1.35			

Yield of commercial check = 14.63 percent sucrose

LSD			
LSD	Between male-sterile means	.05 = 0.23	.01 = 0.31
	Between tetraploid means	.05 = 0.35	.01 = 0.46
	Between triploid means	.05 = 0.93	.01 = 1.22

Minnesota Combining Ability Test

The analysis of variance, mean squares and variance components for tons per acre and sucrose percent are included in Tables 4 and 5. Statistical differences are evident between males and between females for both yield factors. The general trend that greater variation was present between males than between females was noted in this data. Specific combining ability measured by the female × male interaction is not important in this area for either tons per acre or sucrose percent.

The actual yields of the triploids are included in Tables 10 and 11. The same general combining ability trends were evident at this location as was found at the other two locations.

Discussion and Conclusions

The variance components were higher at all locations for the males than for females. This would indicate that the male-sterile types used in this study were genetically more alike than the tetraploids. This reaction should have been expected since all the male-sterile parents except SLC #129 originated from Dr. McFarlane's project. All the tetraploid pollinators originated from the Kleinwanzlebener Saatzucht Company but they had been previously selected for certain diverse agronomic characteristics.

Oldemeyer and Rush (10) found the greater variation between females when studying combining ability in diploids. Actually the magnitude of the general combining ability components of variance depend on the genetic diversity of the parental material.

The predominance of non-significant differences for females crossed to the same male and the occasional non-significant differences for males crossed to the same female would indicate the need of more than one tester. Perhaps a series of three or four genetically diverse (tonnage type, sugar type, etc.) male-sterile lines with varying combining ability would better evaluate tetraploid pollinators than the male-sterile series reported in this paper. Oldemeyer (9) suggested the use of several testers for efficient evaluation of inbreds for combining ability. However, statistical differences were evident between males and females in this study when the diallel averages were compared.

The variance components for general combining ability are greater than those for specific combining ability at all three locations. Thus a screening procedure for evaluating the tetraploid and male-sterile material using a common broad base tester should be effective. Oldemeyer (9) reported that the correlation coefficients between a variety tester and the red beet

Table 10.—Tons per acre for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmic male-sterile types (Minnesota data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	16.16	16.14	14.95	14.64	15.23	16.10	15.64	15.55	NS	
2	15.49	14.82	15.39	14.74	14.15	15.62	14.95	15.02	NS	
3	16.72	15.06	14.58	14.84	15.48	15.39	16.48	15.51	1.44	NS
4	16.28	14.68	16.48	16.19	16.38	16.32	16.91	16.18	NS	
8	15.22	15.16	13.90	14.95	14.90	14.12	15.60	14.84	NS	
9	17.51	16.97	15.40	16.21	15.83	16.37	16.55	16.40	NS	
10	15.64	16.16	15.54	15.53	16.74	15.60	15.66	15.84	NS	
11	16.11	16.24	15.63	15.52	14.78	15.31	16.00	15.65	NS	
13	16.78	16.18	15.24	16.00	15.52	15.96	16.41	16.01	NS	
14	15.54	15.52	16.16	15.42	15.04	15.93	14.39	15.42	NS	
15	16.89	17.03	17.40	17.39	16.68	17.61	17.56	17.22	NS	
16	15.79	15.68	15.80	16.67	15.50	14.97	16.45	15.84	NS	
17	16.34	15.46	15.47	15.23	15.87	16.72	16.03	15.87	NS	
19	16.44	16.54	15.86	16.29	16.30	16.08	16.03	16.22	NS	
20	16.80	16.31	15.97	15.91	16.49	15.42	15.84	16.11	NS	
28	15.28	15.89	15.98	16.46	15.90	15.49	15.27	15.75	NS	
Mean	16.18	15.86	15.60	15.74	15.66	15.80	15.98	15.84		
LSD (0.05)	NS	1.47	1.58	NS	1.55	1.47	1.39			
LSD (0.01)	NS	NS	NS	NS	NS	1.94	1.84			

Yield of commercial check = 15.83 tons per acre

LSD Between male-sterile means	.05 = 0.37	.01 = NS
Between tetraploid means	.05 = 0.56	.01 = 0.74
Between triploid means	.05 = 1.49	.01 = 1.96

Table 11.—Sucrose percentage for the 112 triploid hybrids produced from 16 tetraploid pollinator strains and 7 cytoplasmic male-sterile type (Minnesota data).

Tetraploid pollen parents	Male-sterile diploid parents								L.S.D.	
	2	3	4	5	6	7	8	Mean	.05	.01
61-4T1	16.21	16.22	15.80	16.10	16.24	15.84	16.45	16.12	NS	
2	16.19	15.50	15.71	15.99	16.20	15.85	16.22	15.95	NS	
3	16.25	15.84	16.09	16.13	15.78	15.90	16.06	16.01	NS	
4	16.26	16.41	16.42	15.94	16.24	15.88	16.69	16.26	NS	
8	16.39	16.02	16.10	16.25	16.54	16.82	16.98	16.44	.63	NS
9	15.65	16.36	15.80	16.00	15.42	15.54	15.75	15.79	NS	
10	15.75	15.21	15.54	15.98	15.73	15.72	15.45	15.62	NS	
11	16.09	15.98	15.85	16.20	15.80	15.80	15.62	15.90	NS	
13	16.20	16.02	16.58	16.23	16.08	16.15	16.33	16.22	NS	
14	16.80	16.11	16.10	15.86	16.09	16.23	16.60	16.25	NS	
15	16.00	15.61	15.95	16.09	15.26	16.01	15.88	15.83	NS	
16	16.08	15.84	16.41	15.92	15.91	15.88	16.29	16.04	NS	
17	16.32	15.54	15.89	15.89	16.04	15.59	16.05	15.90	NS	
19	16.31	15.72	16.32	16.11	16.03	15.62	16.58	16.10	NS	
20	16.03	15.88	15.78	15.93	16.50	15.76	16.42	16.04	NS	
28	15.72	14.73	14.62	14.58	15.02	15.32	15.70	15.10	.74	.98
Mean	16.13	15.80	15.92	15.94	15.92	15.86	16.18	15.98		
LSD (0.05)	NS	.74	.74	.71	.67	.66	.63			
LSD (0.01)	NS	.98	.98	.94	.88	NS	.83			

Yield of commercial check = 15.30 percent sucrose

LSD Between male-sterile means	.05 = 0.17	.01 = 0.22
Between tetraploid means	.05 = 0.18	.01 = 0.34
Between triploid means	.05 = 0.69	.01 = 0.90

tester were sufficiently high to consider the red beet a reliable tester parent. Others have considered the red beet cross an adequate early test for combining ability (5, 6, 11).

A red beet tester would eliminate the need of an isolation for each tetraploid population. Hybrids would be distinguished at thinning by the red leaf and hypocotyl color. Preliminary screening with the red beet and a second screening of the selected group with a male-sterile series should thoroughly evaluate a prospective tetraploid parent. A similar program for male-sterile evaluation; that is, male steriles crossed to the red beet followed by selected male steriles crossed to a tetraploid series, should also be effective. With this combining ability information available, specific hybrid types could be combined that should produce a superior hybrid. However, the success of such a program would depend on the true yield of these hybrids. One difficulty may be that the use of a common tester for both parents may result in the selection of genetically similar types which in turn may decrease the yield in the final cross.

The yields of the better triploid hybrids ranged from 5 to 25 percent better than the open-pollinated commercial varieties depending on the location. The diversity of germ plasm; males from Europe, females from the United States sources, may have contributed to the increases in yield. However, the primary question that must be answered before the true value of triploids are known is: "What effect does the polyploid level have in this expression of heterosis?"

The types and amount of disease resistance varied in both the tetraploid and male-sterile diploid parents. This factor could have contributed greatly to the high significance of the genotype × location interaction. The variances for specific combining ability were highly significant in the California and Colorado data where disease complexes were different. These same interactions were insignificant in Minnesota where disease problems are negligible. Thus, it would appear that one of the main factors influencing the yields of the triploids was disease resistance.

Summary

Triploid sugar beet seed was produced in isolated crossing plots using 16 tetraploid pollinator varieties and 7 cytoplasmic male-sterile diploid strains. Yield trials were conducted in California, Colorado and Minnesota, using the 112 possible triploid hybrids. Estimates of general and specific combining ability were calculated by the components of variance method for tons per acre and sucrose percent. The combined analysis indicated that all the interactions with locations were highly sig-

nificant for both factors studied. Thus, local adaption was of major importance in the yielding ability of the hybrids. Individual location tests indicate that specific combining ability as measured by the male × female interaction was important for tons per acre in California and Colorado. The male × female interaction for sucrose percent was significant only in Colorado. Specific combining ability was of little importance in Minnesota. Differences between males and between females was statistically significant at all locations.

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