Performance of Diploid and Triploid Sugar Beet Hybrids from the Same Genetic Source

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Received for publication February 14, 1967

Since discovery of the colchicine method of doubling chromosomes in plants, plant breeders have had a new and revolutionary breeding tool. Shortly following this discovery European sugar beet geneticists and plant breeders began to produce commercial polyploid hybrids by planting tetraploid and diploid seed together in the same seed fields. The resulting seed actually gave rise to a mixture of tetraploid, triploid and diploid plants.

Savitsky (6)[2] has done an excellent job of reviewing the literature on yields of polyploid varieties. He states, "According to the opinions of European breeders a better combination of high sucrose and yield can be obtained at the polyploid level than at the diploid level."

In Canada and the United States excellent yields of triploid hybrids have been reported by Peto and Hill (5) and Savitsky (6). In Savitsky's material, the highest yield of roots and sucrose was observed in male-sterile monogerm triploid hybrids. He concluded that "triploid heredity permits the control of the phenomenon of heterosis itself." (6)

Oldemeyer and Smith (4) state that most of the sugar beet breeding in the United States was in the direction of the production of diploid male-sterile hybrids. Sugar beet breeding methods used parallel those which have been so successful in the development of hybrid maize. However, he also interjected some plant breeding philosophy regarding polyploids: "Sugar beets are different from most crops in that yield is measured on the vegetative organ. It is possible then to make heterosis-polyploid studies at the 2n, 3n and 4n levels, independent of seed yield which is obviously affected by ploidy level. It is generally agreed that heterosis results mainly from the action of dominant genes with a minor role played by epistasis. It would then be postulated that in the absence of a major physi-

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[2] Numbers in parentheses refer to literature cited.

ological upset in the sugar beet plant, 3n and 4n hybrids would offer great possibilities in exploiting heterosis. This is on a purely mathematical basis in that a 3n hybrid plant has one locus in each of three homologous chromosomes which has a chance of receiving a dominant gene as opposed to one locus in each of two chromosomes in a diploid plant. There is a possibility that tetraploid hybrids will be even more superior, particularly if greatly divergent breeding material is brought together. However, to fully exploit this mathematical superiority of a triploid, three divergent lines will be required. Combinations for superior 2n hybrids are rare and it would follow that combinations of inbreds for producing an equivalent potential in 3n hybrids would be even more rare. However, theoretically, little of its additional potential would be needed for it to be superior to a 3n hybrid. Thus, there is genetic theory for the superiority of polyploid hybrids. However, no data are known which would unequivocally confirm a superiority. It is most difficult to design and conduct experiments to elucidate this question of superiority."

The objective of this investigation was to determine what effect the polyploid level plays in the expression of heterosis.

Materials and Methods

Four uniform inbred lines were received from the U. S. Department of Agriculture Sugar Beet Breeding Station at Fort Collins, Colorado. These lines were treated with colchicine and autotetraploid lines were produced. The four original diploid lines and the four newly created inbred tetraploids were each isolated with eight male-sterile lines in 1964. Three of the male-sterile lines were received from the U. S. Department of Agriculture Sugar Beet Breeding Station at Salinas, California. Two of these male steriles, 561HO and 569HO, were inbred and uniform. The other line (569H2) was an F_1 hybrid between 561HO and 569 and was also quite uniform. The remaining male-sterile lines were developed by at least three sib matings and, perhaps, were somewhat more variable.

Inbred line #34 bolted very poorly and only a small amount of seed was produced. This was true for both the diploid and tetraploid isolations. This seed was planted only at Rocky Ford, Colorado. The other isolations produced sufficient diploid and triploid seed on four male-sterile lines to plant a test at four locations, replicated 12 times (Test #1).

Test #1 included hybrids of the following parents:

Male-sterile parents	Male parents (2n and 4n)
63-1HO	52-307
63-2HO	52-407
63-8HO	52-408
569HO	

Test #1 consisted of 12 diploid hybrids, 12 triploid hybrids, four male sterile lines, and the six pollen producing male parents (three diploid and three tetraploid). Two commercial checks were included making a total of 36 entries. The Rocky Ford test had two additional pollen producing entries, inbred #34 (2n and 4n).

The 36 entries were arranged in a split-split plot design. Male parents were main plots, females were sub-plots, and chromosome levels were sub-sub-plots. Chromosome levels represent the difference between diploid and tetraploid pollinators of the same genetic material. In this design, diploid and triploid hybrids from the same genetic material always occurred side by side in the field. Female lines were kept as a group but randomized within groups. Pollen parents were treated similarly. The two commercial checks were kept together but randomized each time. These 36 entries, with the above type of restricted randomization were replicated 12 times and planted at Clarksburg, California; Rocky Ford, Colorado; Mason City, Iowa; and East Grand Forks, Minnesota.

Test #2 was very similar and included hybrids of the following parents:

Male-sterile parents	Male parents (2n and 4n)
63-3HO	52-307
63-5HO	52-407
561HO	52-408
569H2	#34 (Rocky Ford)

The experimental design was the same as Test #1 except only the female parents were included and the test had eight replications. It was not planted in California. Therefore, the Rocky Ford test had 36 entries and the two eastern tests each had 28 entries.

Plots were single rows, 22 inches wide and 35 feet long. The complete plot was harvested for weight and divided into two samples for sucrose determinations. Stands are given as number of beets per 35 feet of row. The Rocky Ford test also was analyzed for purity, amino acids and total nitrogen content of the press juice.

Results and Discussion

Parents

Yield and stand results of parents used in this study are shown in Tables 1, 2, 3 and 4. Yields of the parents in California (Table 1) were high and good stands were obtained. Tetraploid male parents averaged significantly higher in tonnage than diploid male parents. There also was a significant interaction between male parents and chromosome levels for tonnage. This was caused primarily by the exceptionally good yield of the tetraploid parent, 52-307. It outyielded its diploid counterpart by nearly 15 tons.

Male parents differed significantly for all attributes studied. Diploid male parents were significantly higher in percent sugar than the tetraploid parents.

The four female parents differed significantly in percent sugar and tonnage yield, but were nearly equal in stand. Female 63-1HO was a "sugar type" while 63-8HO was a "tonnage type".

Table 1.—Means, LSD, and significant interactions for stand, percent sucrose and tonnage yield of the parents used in the California Test #1 - 1965.

♂ Parent		Stand[1]	% Sugar	Tons per acre
52-307	4n	48.9	12.46	35.42
"	2n	52.2	13.46	20.59
52-407	4n	48.1	10.89	16.28
"	2n	45.7	11.33	20.26
52-408	4n	48.1	11.17	21.88
"	2n	49.5	12.54	24.62
Means	4n	48.4	11.51	24.53
Means	2n	49.1	12.44	21.83
Male parent	LSD (0.05)	2.4	.53	3.15
	(0.01)	NS	.71	4.20
4n vs 2n	LSD (0.05)	NS	.43	2.57
	(0.01)	NS	.58	NS
Male parent × chromosome level		NS	NS	**
♀ Parent				
63-1HO		50.5	15.27	26.63
63-2HO		54.0	14.63	24.02
63-8HO		55.4	13.76	32.02
569HO		50.3	14.73	27.34
LSD (0.05)		NS	.53	3.38
(0.01)		NS	.71	4.56

[1] Number of beets per 35 feet of row.

NS = Non Significant.

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

The parents also produced a good yield at Rocky Ford (Table 2). Significant differences were detected between male parents for stand, percent sugar, and total nitrogen. Significant differences between 2n and 4n pollinators were found for stand and tonnage. In both cases the diploid was higher. However, significant interactions for male parents and chromosome levels were found for stand, percent sugar, tonnage and percent purity. The significant interaction in stand was caused, primarily, by the higher stand of tetraploid #34 over its diploid equivalent. Among the other three male parents, diploids had higher stand counts than their respective tetraploids.

Table 2.—Means, LSD, and significant interactions for stand, yield and chemical analysis of the parents used at Rocky Ford, Colorado in Test #1 and Test #2 - 1965.

♂ Parent		Stand[1]	% Sugar	Tons per acre	% Purity	Total[2] nitrogen
52-307	4n	24.8	11.42	17.22	82.5	.73
"	2n	33.3	12.54	13.94	85.4	.63
52-407	4n	28.8	11.40	10.98	83.6	.90
"	2n	30.8	11.18	19.82	81.7	.93
52-408	4n	21.3	11.74	8.65	83.7	.71
"	2n	27.7	12.18	17.48	83.7	.70
#34	4n	29.3	10.71	15.50	82.9	.90
"	2n	24.3	10.49	11.81	83.0	.86
Means	4n	26.1	11.32	13.09	83.2	.81
Means	2n	29.0	11.60	15.76	83.5	.78
Male Parent						
LSD (0.05)		3.8	.44	NS	NS	.07
(0.01)		NS	.60	NS	NS	.09
4n vs 2n						
LSD (0.05)		2.7	NS	1.51	NS	NS
(0.01)		NS	NS	2.01	NS	NS
Male parent × chromosome level		**	*	**	*	NS
♀ from Test #1						
63-1HO		36.2	13.09	20.80	87.2	.67
63-2HO		35.5	13.20	18.19	86.9	.75
63-8HO		34.2	12.36	24.26	86.5	.78
569HO		32.0	12.03	14.95	85.8	.77
LSD (0.05)		NS	.55	2.61	NS	NS
(0.01)		NS	.74	3.51	NS	NS
♀ from Test #2						
63-3HO		37.8	13.39	20.36	87.5	.65
63-5HO		35.1	12.72	18.79	86.8	.54
561HO		35.0	12.34	14.48	86.5	.70
569H2		33.9	12.50	15.24	87.3	.54
LSD (0.05)		NS	.69	3.46	NS	.10
(0.01)		NS	NS	4.66	NS	.14

[1] Number of beets per 35 feet of row.
[2] Percent on dissolved solids.
NS = Non Significant.
* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Diploid male parents, 52-307 and 52-408, exceeded their tetraploid counterparts in percent sugar. The opposite was true for 52-407 and #34. Tetraploid parents, 52-307 and #34, were superior in tonnage yield over their respective diploids. Diploid parents, 52-407 and 52-408, yielded nearly twice as much as their respective tetraploid counterparts.

Significant differences were detected between females (Tables 1 and 2) for percent sugar and tonnage in both Test 1 and 2. Females in Test 2 were significantly different in total nitrogen. Test 1 again indicates 63-8HO is outstanding in tonnage yield but low in percent sugar. In Test 2, 63-3HO is the outstanding female. It is the highest in both tonnage and percent sugar.

Table 3 gives the stand and yield performance of parents grown in Mason City. Plants in these tests became extremely

Table 3.—Means, LSD, and significant interactions for stand, percent sugar and tonnage yield of parents used at Mason City, Iowa in Test #1 and Test #2 - 1965.

♂ Parent		Stand[1]	% Sugar	Tons per acre
52-307	4n	34.7	12.77	10.60
"	2n	38.0	13.43	8.18
52-407	4n	27.0	11.77	6.66
"	2n	33.2	11.32	10.81
52-408	4n	21.8	12.81	5.37
"	2n	29.2	12.69	5.50
Means	4n	27.8	12.45	7.54
Means	2n	33.5	12.48	8.16
Male parent	LSD (0.05)	4.0	.74	1.51
	(0.01)	5.3	.98	2.02
4n vs 2n	(0.05)	3.3	NS	NS
	(0.01)	4.4	NS	NS
Male parent × chromosome level		NS	NS	**
♀ from Test #1				
63-1HO		36.8	13.22	8.21
63-2HO		33.9	13.18	8.51
63-8HO		33.6	12.79	11.74
569HO		34.0	13.72	8.84
LSD (0.05)		NS	NS	2.46
(0.01)		NS	NS	NS
♀ from Test #2				
63-3HO		33.6	13.13	12.93
63-5HO		35.9	12.59	12.46
561HO		37.9	12.70	14.07
569H2		34.1	12.79	13.18
LSD (0.05)		NS	NS	NS
(0.01)		NS	NS	NS

[1] Number of beets per 35 feet of row.
NS = Non Significant.
* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

wilted due to drought. A week or more of severe wilting reduced the yield and perhaps the reliability of the test.

Significant differences were detected between male parents for all attributes studied (Table 3). There was a significant difference in stand between tetraploid and diploid parents. Diploids had a greater number of beets per plot. There also was a significant interaction between chromosome levels and male parents for tonnage yield. This interaction was again caused, primarily, by the high yield of the tetraploid parent 52-307 over its diploid counterpart.

Females in both tests reacted very similar (Table 3). The only significant difference which was detected between male steriles was for tonnage in Test 1. The high yielding ability of 63-8HO was again evident.

Table 4.—Means, LSD, and significant interactions for stand, percent sugar and tonnage yield of parents used at East Grand Forks, Minnesota in Test #1 and Test #2 - 1965.

♂ Parent		Stand[1]	% Sugar	Tons per acre
52-307	4n	18.3	11.98	6.38
"	2n	20.7	13.46	5.21
52-407	4n	16.8	10.24	3.28
"	2n	22.2	10.51	7.80
52-408	4n	13.0	11.28	2.44
"	2n	17.3	11.93	4.70
Means	4n	16.0	11.17	4.03
Means	2n	20.1	11.97	5.09
Male parent	LSD (0.05)	2.8	.40	.84
	(0.01)	3.8	.54	1.12
4n vs 2n	(0.05)	2.3	.33	.69
	(0.01)	3.1	.44	.92
Male parent × chromosome		NS	*	**
♀ from Test #1				
63-1HO		17.8	12.40	5.49
63-2HO		19.2	12.52	6.60
63-8HO		20.6	12.65	7.71
569HO		18.7	12.27	4.75
LSD (0.05)		NS	NS	1.24
(0.01)		NS	NS	1.67
♀ from Test #2				
63-3HO		19.8	12.52	7.55
63-5HO		23.0	12.28	8.32
561HO		23.2	12.22	7.30
569H2		17.6	12.06	5.64
LSD (0.05)		3.5	NS	1.58
(0.01)		4.7	NS	NS

[1] Number of beets per 35 feet of row.
NS = Non Significant.
* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Stand count and yield of parents grown at East Grand Forks are given in Table 4. These tests were planted extremely late. Emergence was poor; therefore, the yields are extremely low. Significant differences were detected between male parents for all characters studied. Diploid male parents were superior to tetraploids for all characters. Significant male parent × chromosome level interactions were detected for percent sugar and tonnage. The range of sucrose content between the 2n and 4n equivalents was not constant. The tonnage interaction was again caused primarily by the good yield of 52-307 at the tetraploid level.

Significant differences were detected between females in Test 1 for tonnage (Table 4). The male sterile, 63-8HO, was the highest tonnage producer; 569HO was the lowest. In Test 2 significant differences were detected for stand and tonnage. The male sterile, 63-5HO, was the best yielding female.

In general, diploid male parents had better stands, higher percent sucrose and yield than their tetraploid counterparts. The male parent, 52-307 at the tetraploid level, was a definite exception to this trend. It outyielded its diploid equivalent in tonnage at all locations and contributed to the significant interaction, male parent × chromosome levels, in all tests. Other significant interactions were found but they were not consistent over all locations. The male sterile, 63-8HO, exhibited a high tonnage potential at all locations. However, it was one of the lowest in percent sucrose.

Hybrids

The mean performance of male parents in hybrid combination for all tests and locations is given in Table 5. The average yielding ability of male parents was fairly constant within locations (Tests 1 and 2), but differed between locations.

General combining ability of the females used in hybrid combination is shown in Table 6. Significant differences were found between male steriles at all locations. In Test 1, 63-2HO, had the highest percent sugar at all locations; 63-8HO was the highest tonnage producer at two locations. In Test 2, 63-3HO, was the highest in percent sugar at all locations. It also was the highest in tonnage at Rocky Ford and Mason City.

Yield results of the females "per se" suggest that 63-8HO is a tonnage type and that 63-3HO has good sucrose content and yield (Tables 1, 2, 3, 4). These characteristics were again evident in hybrid combination.

General combining ability of triploid and diploid hybrids is given in Table 7. In all tests at all locations, diploid hybrids

Table 5.—General combining ability for stand, yield and chemical composition of male lines (averaged over all female combinations and chromosome levels) at 4 locations.

	Test #1					Test #2				
♂ Parent	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]
Rocky Ford						36.2	12.80	24.66	87.2	.54
52-307	33.7	12.77	26.48	86.7	.65	36.9	12.48	27.33	86.2	.65
52-407	34.0	12.51	29.99	85.8	.77	35.1	12.90	25.82	87.4	.56
52-408	32.5	12.80	28.16	86.6	.70	31.9	12.16	18.04	86.5	.57
#34										
LSD (0.05)	NS	NS	2.58	NS	.06	3.6	.39	2.04	.9	.06
(0.01)	NS	NS	NS	NS	.09	4.8	.53	2.78	NS	.08
Mason City										
52-307	40.0	12.97	13.54			41.4	12.95	17.16		
52-407	39.6	12.22	14.19			40.8	12.34	16.60		
52-408	36.2	12.02	13.30			39.3	12.92	17.45		
LSD (0.05)	1.3	NS	NS			NS	.31	NS		
(0.01)	1.7	NS	NS			NS	.43	NS		
East Grand Forks										
52-307	21.8	12.49	8.83			22.6	12.21	9.62		
52-407	21.7	11.38	9.53			22.7	11.27	11.02		
52-408	20.8	12.02	8.73			23.4	11.89	10.03		
LSD (0.05)	NS	.29	.56			NS	.47	NS		
(0.01)	NS	.40	NS			NS	.66	NS		
Clarksburg										
52-307	52.4	14.37	37.79							
52-407	53.0	13.29	38.20							
52-408	51.6	13.63	43.78							
LSD (0.05)	NS	.63	1.96							
(0.01)	NS	.86	2.66							

NS = Non Significant
[1] Number of beets per 35 feet of row.
[2] Percent on dissolved solids.

Table 6.—General combining ability for stand, yield and chemical composition of male sterile lines (averaged over all male combinations and chromosome levels) at 4 locations.

	Test #1					Test #2					
♀ Parent	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]	♀ Parent	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]
Rocky Ford											
63-1HO	33.5	12.75	28.14	86.7	.67	63-3HO	36.0	12.78	25.59	86.8	.59
63-2HO	33.4	13.07	27.95	87.0	.70	63-5HO	37.2	12.72	25.41	87.1	.57
63-8HO	33.7	12.71	29.58	86.0	.74	561HO	34.5	12.44	23.03	86.8	.58
569HO	33.0	12.24	27.16	85.9	.70	569H2	32.6	12.40	21.81	86.5	.59
LSD (0.05)	NS	.25	1.45	.7	.04		1.4	.25	1.40	NS	NS
(0.01)	NS	.32	NS	.9	.05		1.9	.34	1.86	NS	NS
Mason City											
63-1HO	38.2	12.98	13.24			63-3HO	42.6	12.92	17.20		
63-2HO	39.3	12.59	13.54			63-5HO	41.3	12.70	17.10		
63-8HO	38.6	12.28	13.33			561HO	40.7	12.68	17.15		
569HO	38.3	11.79	14.59			569H2	37.4	12.66	16.84		
LSD (0.05)	NS	.48	.86				2.4	NS	NS		
(0.01)	NS	.64	1.14				3.3	NS	NS		
East Grand Forks											
63-1HO	21.6	11.89	8.65			63-3HO	23.2	12.08	10.48		
63-2HO	21.1	12.11	9.10			63-5HO	24.2	11.47	11.00		
63-8HO	22.4	11.87	9.25			561HO	22.4	11.71	9.96		
569HO	20.6	11.98	9.04			569H2	21.7	11.90	9.46		
LSD (0.05)	.9	NS	NS				1.3	.19	.70		
(0.01)	1.3	NS	NS				1.7	.26	.93		
Clarksburg											
63-1HO	51.4	13.95	39.83								
63-2HO	52.4	14.04	38.45								
63-8HO	53.2	13.44	40.10								
569HO	52.4	13.61	41.45								
LSD (0.05)	NS	.26	1.48								
(0.01)	NS	.35	1.96								

[1] Number of beets per 35 feet of row.
[2] Percent on dissolved solids.
NS = Non Significant.

Table 7.—General combining ability of triploid and diploid hybrids at 4 locations.

	Test #1					Test #2				
Hybrid	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]	Stand[1]	% Sugar	Tons per acre	% Purity	Total nitrogen[2]
Rocky Ford										
3n	32.0	12.57	27.12	86.3	.71	32.8	12.55	22.41	86.8	.58
2n	34.8	12.81	29.28	86.4	.70	37.3	12.62	25.51	86.8	.59
LSD (0.05)	1.3	.12	.92	NS	NS	1.4	NS	.69	NS	NS
(0.01)	1.7	.16	1.23	NS	NS	1.9	NS	.91	NS	NS
Mason City										
3n	37.2	12.26	12.96			39.0	12.54	16.21		
2n	40.0	12.55	14.39			42.0	12.93	17.94		
LSD (0.05)	1.5	NS	.48			1.9	.14	.73		
(0.01)	1.9	NS	.64			2.6	.18	.97		
East Grand Forks										
3n	20.5	11.63	8.18			21.8	11.42	9.29		
2n	22.4	12.30	9.80			23.9	12.16	11.15		
LSD (0.05)	.7	.16	.35			1.1	.34	.49		
(0.01)	.9	.21	.46			1.5	.46	.66		
Clarksburg										
3n	50.5	13.49	38.23							
2n	54.3	14.03	41.68							
LSD (0.05)	.8	.09	.87							
(0.01)	1.3	.12	1.15							

[1] Number of beets per 35 feet of row.
[2] Percent on dissolved solids.
NS = Non Significant

appear superior to triploid hybrids for stand, percent sucrose and tonnage. No significant differences were found for percent purity or total nitrogen.

Yields of the diploid and tetraploid parents indicate that diploids are potentially higher yielding except for the tetraploid parent 52-307. At all locations and in both tests, significant interactions between male parents and chromosome levels were detected for tonnage. These significant interactions for tonnage were caused primarily by the high yielding ability of hybrids which had tetraploid 52-307 as a pollen parent.

These results do not agree with results obtained by Savitsky (6), Knapp (2), or many European investigators cited by Savitsky (6), or previous investigations by American Crystal Sugar Company (1). Previous tests by American Crystal were conducted in California in the fall of 1963 and the spring of 1964. Pollen parents were produced at Salinas. The diploid pollen parent was 663. The tetraploid derived from this number was labeled 163T. They were each crossed with the same four male-sterile lines. Results of both harvests are summarized in Table 8.

Table 8.—Comparison of 2n and 3n hybrids of the same parental material (1963-64).

	Acre yield			
	Sugar	Beets	Sucrose	No. of beets per 100′ of row
	pounds	tons	percent	
Diploids	7648	25.52	14.99	130
Triploids	8998	31.16	14.44	130

These results indicate a superiority of triploids and do not agree with the results reported in this paper. Some of the conflict may be due to differential stands. The average tonnage yield of each diploid hybrid in the present study was approximately ten percent higher than its corresponding triploid hybrid. Likewise, stand counts were approximately ten percent higher. Low stand counts were probably associated with poor germination and field emergence. If stands had been more uniform the difference between 2n and 3n hybrids may not have been as great.

Individual test crosses were compared to the performance of their parents in Test 1 for pounds of sugar per acre, tonnage and percent sucrose (Table 9). If a test cross was significantly above the mean of the high parent, it was considered to be an expression of heterosis. If a test cross significantly exceeded the mean of its parents, it was considered to be an expression of dominance. Remaining crosses were divided into two classes; those numerically above and those numerically below the mean of their respective parents.

Most of the crosses showed either heterosis or dominance for pounds of sugar per acre and tonnage at all four locations (Table 9). Fewer test crosses showed heterosis and/or dominance for percent sucrose than for either pounds of sugar per acre or tonnage. This concurs with results reported by Oldemeyer and Rush

Table 9.—Classification of 24 test crosses relative to the performance of their parents in Test #1 grown at 4 locations.

Location and classification	Lbs sugar per acre	Tons per acre	Percent sucrose
Rocky Ford			
Number showing heterosis	21	20	1
Number showing dominance	3	4	6
Of the remaining crosses:			
Number above $\frac{P_1 + P_2}{2}$	0	0	16
Number below $\frac{P_1 + P_2}{2}$	0	0	1
Mason City			
Number showing heterosis	11	16	0
Number showing dominance	7	8	0
Of the remaining crosses:			
Number above $\frac{P_1 + P_2}{2}$	6	0	5
Number below $\frac{P_1 + P_2}{2}$	0	0	19
East Grand Forks			
Number showing heterosis	17	17	1
Number showing dominance	7	6	0
Of the remaining crosses:			
Number above $\frac{P_1 + P_2}{2}$	0	1	8
Number below $\frac{P_1 + P_2}{2}$	0	0	15
Clarksburg			
Number showing heterosis	19	19	0
Number showing dominance	5	4	21
Of the remaining crosses:			
Number above $\frac{P_1 + P_2}{2}$	0	1	2
Number below $\frac{P_1 + P_2}{2}$	0	0	1

(3) for yield and percent sucrose of test crosses. All test crosses in the present study were above the averages of their respective parents for pounds of sugar per acre and tonnage at all four locations. Many test crosses were below the average of their parental means in percent sucrose at two of the four locations.

The genetic material used as parents in these tests was very limited, consisting of four pollen parents and eight male-sterile parents. Sampling of additional genetic material could produce different results. The fact that several significant interactions between male parents and chromosome levels did exist was a definite indication that some parents will produce better hybrids at a diploid level, while others will produce higher yielding hybrids at a triploid level. There also were four significant female × chromosome level interactions. These interactions indicate that some females may yield higher with a diploid pollinator while others will yield higher with a tetraploid pollinator.

There were two significant interactions between male parents × females. This is an indication of the existence of specific combining ability. The fact that there were only two such interactions and one of these was for stand, which could have been influenced by thinning procedures, indicate that these interactions are probably not of great importance.

Summary

Four inbred diploid lines of sugar beets and their tetraploid counterparts were each isolated with eight male-sterile lines in 1964. The hybrid seed (2n and 3n), and male and female parents were planted in replicated tests at four locations in 1965.

In general, diploid male parents had better stands, higher tonnage and percent sucrose than their tetraploid counterparts. Significant differences in general combining ability for tonnage and percent sucrose were found between the male steriles at all locations. Diploid hybrids were found to be superior to triploid hybrids for stand, tonnage and percent sucrose. No significant differences were found for percent purity or total nitrogen.

The genetic material used as parents in this study was limited. Sampling of additional genetic material could produce different results.

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