Heterosis in Sugar Beet Single Crosses

DEWEY STEWART, JOHN O. GASKILL and G. H. COONS[1]

The investigations by Stewart, Lavis, and Coons (5)[2] on hybrid vigor in sugar beets were based upon 41 F_1 hybrids that were compared in replicated field tests with the inbred parents and with a commercial brand of sugar beets for root weight, sucrose percentage, and sugar production. The breeding material employed did not permit F_1 plants to be differentiated at thinning time from selfs. However, with many of the populations identification of F_1 plants, chiefly by foliage characteristics, was attempted shortly before harvest. Whenever seed collected from the strains entering a cross had not been separately kept according to seed-bearing strain, the progeny was evaluated without attempt to eliminate selfs. In 31 of 41 cases tested, root weight of the hybrid was significantly greater than the root weight of parent strains appropriate for the comparison. The average gain in root weight of hybrid over parental mean was 42.5 percent, but the authors recognized that this percentage is greatly influenced by the relative yielding abilities of the inbreds entering a given cross. The average sucrose percentage of the hybrids was slightly lower than the average of the parent inbreds, but the difference was not significant. Tn the tests reported, effects attributable to resistance to leaf spot (*Cercospora beticola* Sacc.) of certain inbreds or hybrids could not be separated from effects associated with vigor of hybridity, *per se*. It is considered, in general, that the performances of the hybrids when compared, either with maternal parent, with the mean of parents, or with the commercial brand, were so consistently superior throughout the tests that adequate evidence of heterosis was furnished.

For continuation of the study of heterosis in sugar beets, hybrids produced from inbreds obtained in the sugar beet leaf spot resistance breeding investigations of the Division were utilized. The inbreds under consideration are probably very superior with respect to root weight, sucrose percentage and other characters to those previously mated for hybrid-vigor studies. Eight inbreds had been selfed for three or more generations, three for two generations, one for one generation. Two mass selected varieties were included, one (Synthetic Check) as a top-cross parent, the other (U.S. 22) as a maternal parent.

The experimental work to be reported is, therefore, based upon inbreds of entirely different potentialities. In some other respects the experiments differ from the earlier work. The known inheritance

[1]Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture.

[2]Italic numbers in parentheses refer to literature cited.

of hypocotyl color *(4)* was made use of to identify hybrids in the progenies obtained from the various matings. A single dominant factor, R, has been shown to bring about pink hypocotyl color of seedlings as well as pink color in the bud scales of mature sugar beet roots. If a plant that is double recessive for this color character (rr) is pollinated with pollen from a plant carrying the dominant character, either as RR or Rr, the pink hypocotyl color or pink color in the apical bud identifies F_1's in the progeny. The results reported here deal entirely with hybrid populations of the various crosses that were identified in this way. The experimental work was done in practical absence of leaf-spot attack so that effects of the disease, either in depressing yields of susceptible varieties or in permitting leaf spot resistant varieties to show relatively better yields than susceptibles, were avoided.

Methods

Source of Seed.—The hybrid sugar beet seed for the experiments was produced in seed plots designated as "master crossing plots" in which several to many inbred strains, double recessive for hypocotyl color (rr), were exposed to pollen from a single "master" strain of RR or Rr type. In the seed plot all odd-numbered rows were planted with RR (or Rr) sugar beet roots ot a single inbred strain or of a commercial type. This required that roots having pink or red apical buds be chosen from this pedigree group to plant these rows. Green hypocotyl plants (rr) of a number of inbred strains of sugar beet were set out as groups in the even-numbered rows. In practice this simply required selection of roots whose apical buds did not show any indication of pink or red coloration. Pollination could occur among all the strains represented in the plot, but the only source of the R gene was from the "master" strain planted in the alternating rows. Seed was harvested separately from the green hypocotyl strains. For most of the strains the roots planted in the seed plot were essentially unselected and comprised the general run for the strain concerned. With strains heterozygous for the hypocotyl color character, it was, of course, necessary to pick either green or pink hypocotyl plants according to the particular requirement to be met.

Field Plot Methods.—The hybrids as obtained from the master crossing plots were evaluated in comparison with the parental sugar beet strains and Synthetic Check in tests conducted at Ault, Colo. Plot techniques in general use in sugar beet experiments were followed. In 1942, 32 varieties, including hybrids, inbreds, U. S. 22, and Synthetic Check, were grown in an 8-times-replicated experiment of Equalized Random Block design. However, one entire replication of 32 plots was deleted because of field irregularity, and the results were

analyzed statistically as a randomized block design with seven replications. In 194:5, 40 varieties including hybrids, inbreds, and Synthetic Check were grown in an 8-times replicated experiment, also of Equalized Random Block design. The entire experiment was harvested and the results were analyzed statistically by the analysis of variance method appropriate for this design.

Individual plots were four rows wide and 23 to 24 feet long, a net row length of 40 to 42 feet being harvested. The rows were 20 inches apart. The fields were cross marked, before thinning, to facilitate accurate spacing of plants at 12-inch intervals in the row.

Plots planted with seed harvested from the green bud mother roots of the master crossing plots were thinned to leave identified (pink hypocotyl) hybrids insofar as possible. Plots planted to inbreds or varieties such as Synthetic Check or U. S. 22 were thinned without regard to hypocotyl color. At harvest, data were taken only from competitive beets from the inner rows of each plot. A plant was judged to be competitive if its immediate neighbors in the same row and in the rows to the right and left were in approximately their proper places. Plants judged to be non-competitive were not harvested. In plots containing F_1 hybrids all roots were examined after they were lifted, and those showing pink or red color at the bases of the petioles or in the scales of the apical buds were separated from those not showing such color. The latter were probably also hybrid, but the pollen parent could not be positively identified. The records for F_1's here reported are based entirely upon roots identified as described.

From the average root weight as obtained from the washed roots of a given plot, the yield for 100 percent stand was computed to the acre basis. Sucrose percentage was determined by the Sachs-LeDocte method. In the 1942 tests the roots from a plot were divided at random into two groups of approximately the same number of roots, and from each group a composite pulp sample was obtained. In the 1948 tests 25 roots were taken at random, and a single composite pulp sample was obtained. Analyses for sucrose percentage were made in duplicate on this pulp. If the two readings were not in close accord, new analyses were made on a remnant pulp sample that had been held in a refrigerator pending the checking of the pairs of sucrose readings.

Experimental Results

The pollen parents of the hybrids in both tests were U. S. 215, U. S. 216, and Synthetic Check, designated in the tabulation as "A", "B", and "Syn. Check," respectively. U. S. 215 is an inbred that is characterized by its high root yield. The sucrose percentage of the roots is about average in comparison with the general sucrose range of sugar beet varieties. The root yield, however, overcompensates for

the moderate sucrose quality, so that this inbred produces more sugar per acre than the majority of commercial varieties with which it has been compared. It has only moderate resistance to leaf spot. U. S. 216, on the other hand, classifies as a high sucrose type. The superior sucrose percentage of U. S. 216, in comparison with commercial varieties, largely compensates for its root yield, which may fall significantly below that of commercial varieties with which it has been compared. U. S. 216 is very high in leaf spot resistance. U. S. 215 and U. S. 216 are components of F7. S. 215 x 216, the leaf spot resistant variety introduced by the Division *(2).* To produce this variety, equal quantities of seed of the two inbreds are pooled and a seed crop is produced from the mixture by the field-overwintering method. Therefore the seed obtained, designated as U. S. 215 x 216, actually consists of the single-cross hybrid plus seed of the two parental strains. The variely designated as Synthetic Check was obtained by pooling equal quantities of seed of nine European brands of sugar beet and producing a seed crop in New Mexico by the field-overwintering method from this mixture. As a top-cross parent it may be considered to sample the general run of European commercial brands of sugar beet. In tests conducted over a number of years by the Division, Synthetic Check has given a performance equivalent to the best European tonnage types. In the absence of leaf spot it is a high-yielding variety, moderately high in sucrose, and is capable of producing a fairly high yield of sugar per acre. It therefore can serve as a comparator for appraisal of the various hybrids in terms of performance of European tonnage varieties.

In 1942, hybrids of U. S. 22 and of five inbred strains with the three master strains were evaluated. Tn 1943, hybrids of seven inbred strains with the three master strains were tested. The inbreds used as maternal parents are designated in the tabulations with capital letters. The symbols are identified in table 1, where, to complete the record, details of the pedigrees of the inbreds are given. The 1929 seed number is cited in the table to permit connecting certain strains with breeding lines that have been listed elsewhere *(1).*

It is probable that the inbred designated as B' and used as maternal parent did not differ appreciably from Inbred B used as pollen parent. The mating B' x B, is essentially sibbing and need not be considered. Hence, in the two tests a total of 35 hybrids were studied, 3 of the 35 occurring in both tests. With respect to the pollen parents, the hybrids fall into groups of 12, 11, and 12, corresponding to strains A, B, and Synthetic Check, respectively. Twenty-one of the hybridizations are between inbred strains, 11 are top crosses, and 3 are hybrids of U. S. 22 with the 3 master strains.

Table 1.—Description of inbred varieties and of economic varieties used in the tests in 1942 and 1943.

Code designation used in text	Strain or variety: Name of variety	Sugar Plant Inv. seed number	Generations selfed	Source or pedigree designation	1929 seed number
		♂ Pollen Parents			
A	U. S. 225	2-294-0	8	*1846	{4793-29
B	U. S. 216	2-1007-0	4	*1838	{4795-29
Synthetic Check	Commercial	F. C. Acc. 1055	0	European Brands†	4516-29
		♀ Parents			
B'	U. S. 216	1-1007-0	4	*1838	4516-29
D	...	1-1024-0	4	*2140	4874-29
D'	...	1-1025-0	5	*2140	4874-29
E	...	1-1001-0	7	*1513	4780-29
F	...	1-1004-0	7-8	*1732-3	{7489-24}
R	...	0-1018-0	6	*1991	3444-29
S	...	2-1020-0	2 or more	La Royale‡	
T	...	2-1018-0	1	Old Type‡	
U	...	2-1016-0	3	Pioneer‡	
V	...	2-1014-0	2	Schreiber‡	
W	...	0-1043-0	2	Complex* hybrid	{20416-08}
U. S. 22	U. S. 22	SL 722	0	Salt Lake City, Ut.	

*The strains indicated wore obtained from mass selected breeding stocks received in 1915 by W. W. Tracy, Jr., from F. J. Pritchard. There is no history of selfing prior to Tracy's work. 1915-1929. The old accession numbers were retained in the records as a convenient designation for the lines.

†Synthetic Check as used in these tests was produced by pooling equal quantities of seed of 9 European brands of sugar beet and growing a seed crop from the mixture.

‡European commercial brands of sugar beet.

A mass selected curly top resistant variety obtained from Dr. F. V. Owen.

The data in tables 2 and 3 may first be considered to determine the general effects of hybridity. It is to be noted that root weights of the hybrids exceed the mean root weights of the respective parents 30 times out of a possible 38. In Sucrose percentage, the hybrids exceed the parental means 28 times out of 38. In sugar per acre, the hybrids exceed the parental means in 32 of the 38 comparisons. If the data for these attributes are analyzed by Student's method as a series of paired comparisons, the hybrids, as a class, are found to be significantly superior to the parental means, considered as a class.

It is possible also to make various other group comparisons. Comparisons in terms of the mother line afford very decisive evidence of the vigor of hybridity. In table 2 the average percentage sucrose for six hybrids having A as pollen parent is significantly below the average for the six mother parents. However, both the average root yield and the average gross-sugar yield for the six hybrids are significantly above the corresponding means for the mother strains. The

Table 2.—Comparison of 17 hybrids and of their respective parent strains for root and sugar yields and for sucrose percentages. Similar comparisons of the hybrids with Synthetic Check are also given: Ault, Colo., 1942. (Data for individual inbreds and hybrids are given as 7-plot averages.)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
Synthetic Check	15.77	.....	100.0	14.4	.....	100.0	2.27	.....	100.0
U. S. 215 A	18.09	.....	114.7	13.6	.....	94.4	2.47	.....	108.8
U. S. 216 B	12.72	.....	80.7	15.8	.....	109.7	2.00	.....	88.1
Mean (a) ♂ parents	15.53	.....	98.5	14.6	.....	101.4	2.25	.....	99.0
Inbred B'	14.20	.....	90.0	16.2	.....	113.2	2.33	.....	102.6
Inbred D	17.29	.....	109.6	13.4	.....	93.1	2.32	.....	102.2
Inbred D'	16.25	.....	103.0	14.2	.....	98.6	2.30	.....	101.3
Inbred E	13.69	.....	86.8	15.3	.....	106.3	2.10	.....	92.5
Inbred F	12.65	.....	80.2	15.3	.....	106.3	1.94	.....	85.5
U. S. 22	15.45	.....	98.0	14.7	.....	102.1	2.28	.....	100.4
Mean (b-1) ♀ parents	14.94	.....	94.7	14.9	.....	103.5	2.21	.....	97.4
Mean (b-2) ♀ parents*	15.07	.....	95.5	14.6	.....	101.3	2.19	.....	96.4
B' x A	16.53	102.1	104.8	15.4	103.0	106.9	2.56	107.5	113.7
D x A	19.51	110.3	123.7	14.0	103.7	97.2	2.73	114.6	120.2
D' x A	16.37	95.3	103.8	13.6	97.8	94.4	2.22	93.5	98.2
E x A	17.19	103.2	109.0	14.2	98.3	98.6	2.45	107.2	107.9
F x A	15.76	102.5	99.9	13.8	95.5	95.8	2.18	98.9	96.0
U. S. 22 x A	18.08	107.5	114.3	13.9	98.2	96.5	2.51	105.7	110.5
Mean (c-1) 6 hybrids	17.23	104.3	109.3	14.2	99.4	98.2	2.45	104.5	107.5
Mean (c-2) 5 hybrids*	17.37	104.8	110.1	13.9	98.7	96.5	2.42	103.9	106.6
B' x B**	(12.80)	(95.5)	(81.8)	(16.1)	(100.3)	(111.8)	(2.08)	(96.1)	(91.6)
D x B	16.94	112.0	107.4	14.8	101.4	102.8	2.51	116.2	110.6
D' x B	15.09	104.2	95.7	15.2	102.0	106.3	2.31	107.4	101.8

Table 2—Continued)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
E x B	15.11	114.4	95.8	16.8	103.0	116.7	2.54	123.9	111.9
F x B	14.82	116.8	94.0	16.3	104.8	113.2	2.42	122.8	106.6
U. S. 22 x B	15.41	109.4	97.7	15.9	104.3	110.4	2.45	114.5	107.9
Mean (d-1) 6 hybrids**	.....	.....	.....	.....	.....	.....	.....	.....	.....
Mean (d-2) 5 hybrids*	15.47	111.5	98.1	15.8	104.1	109.9	2.46	117.0	107.8
B' x Syn. Check	14.97	99.6	94.9	15.9	103.6	110.4	2.38	103.5	104.8
D x Syn. Check	16.96	102.6	107.5	14.3	102.9	99.3	2.42	105.4	106.6
D' x Syn Check	15.07	100.4	101.9	14.4	100.7	100.0	2.30	100.7	101.3
E x Syn. Check	15.21	103.9	97.1	15.4	103.7	106.9	2.36	103.0	104.0
F x Syn. Check	15.72	110.6	99.7	14.5	97.6	100.7	2.29	106.8	100.9
U. S. 22 x Syn. Check	14.93	95.6	94.7	14.5	99.7	100.7	2.15	94.9	95.2
Mean (e-1) 6 hybrids	15.56	102.1	99.3	14.8	101.4	103.0	2.32	103.6	102.1
Mean (e-2) 5 hybrids*	15.89	102.6	100.2	14.6	100.9	101.5	2.31	103.6	101.6
Diff. required for significance, odds 10:1—									
Between individual inbreds or hybrids	1.34	.....	11.7	1.1	.....	7.5	0.34	.....	15.0
Between hybrids and mean of parents	1.59	.....	.....	0.96	.....	.....	0.29	.....	.....
Between means of 5	0.82	.....	5.2	0.50	.....	2.5	0.15	.....	6.6
Between means of 6	0.75	.....	4.8	0.45	.....	3.1	0.14	.....	6.2

*Inbred B' and its hybrids were omitted in computation of means b-2, c-2, d-2, and e-2,
**Since B' x B is not a true hybrid, mean d-1 is not comparable with means b-1, c-1, and e-1.

means for the five hybrids having B as pollen parent are significantly higher than the corresponding means for the maternal parents in both sucrose percentage and gross-sugar yield. In average yield of roots, also, these five hybrids are higher than their parents but not significantly so. The average sucrose percentage for the six hybrids stemming from Synthetic Check as pollen parent is practically identical with that of the six mother strains, but in average root yield and gross-sugar yield these hybrids exceed the mother parents by amounts which closely approach significance.

In table 3, with but one exception, the averages for each group of seven hybrids are significantly above the corresponding averages for the seven mother parents in root yield, sucrose percentage, and gross-sugar yield. The only exception is the average sucrose percentage for the hybrids involving paternal parent A. This average is below that of the mother strains but not significantly so.

If comparisons are made on the basis of the performance of Synthetic Check, it will be noted that the three pollen parents average in root weight only 98.5 and 95.1 percent of this standard, the depression in average yield being traceable entirely to U. S. 216. The inbreds and U. S. 22 used as mother parents in the 1942 tests and the inbreds used as mother parents in the 1943 tests, average, in root weight, respectively, 94.7 and 95.2 percent of Synthetic Check. Only four maternal inbreds have higher root yields. None is significantly higher. The mean root weights of the hybrids in tables 2 and 3 are not in any case significantly lower than the root weight of Synthetic Check; when A is pollen parent the mean weights are substantially if not significantly higher. In sucrose percentage, it is probable that the means of hybrids in table 2 or 3 do not differ significantly from Synthetic Check except when Tnbred B was the pollen parent (both tables) and when Synthetic Check was the pollen parent (table 3 only). The comparisons for sugar per acre are of especial interest. As an average, the hybrids reported in table 2 are considerably better than Synthetic Check where either A or B was the pollen parent but differ very little from Synthetic Check where that variety is shown as the pollenizer. The averages for the hybrids reported in table 3 are all substantially higher in sugar production than Synthetic Check.

The evidence clearly indicates that, as a result of heterosis, hybrids may show increased root weight, higher sucrose percentage, and consequently greatly augmented sugar production over what is indicated by averaging the results obtained from the parental strains. Similarly, the hybrids tend to exceed the maternal strains in productiveness.

Whether the increase in productivity, attributable either to im-

Table 3.—Comparison of 21 hybrids and of their respective parent strains for root and sugar yields and for sucrose percentages. Similar comparisons of the hybrids with Synthetic Check are also given: Ault, Colo., 1943. (Data for individual inbreds or hybrids are given as 8-plot averages.)

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
Synthetic Check	16.41	.....	100.0	14.79	.....	100.0	2.426	.....	100.0
U. S. 215 A	17.17	.....	104.6	14.54	.....	98.3	2.505	.....	103.3
U. S. 216 B	13.23	.....	80.6	16.10	.....	108.9	2.144	.....	88.5
Mean (a) ♂ parents	15.60	.....	95.1	15.14	.....	102.4	2.359	.....	97.3
Inbred –B	13.36	.....	81.4	15.77	.....	106.6	2.117	.....	87.3
Inbred –D	16.16	.....	98.4	15.23	.....	103.0	2.468	.....	101.7
Inbred –S	16.64	.....	101.4	15.26	.....	103.2	2.556	.....	105.4
Inbred –T	15.64	.....	95.3	14.85	.....	100.4	2.339	.....	96.4
Inbred –U	17.31	.....	105.5	15.83	.....	107.0	2.741	.....	113.0
Inbred –V	14.90	.....	90.8	14.71	.....	99.5	2.218	.....	91.4
Inbred –W	15.36	.....	93.6	14.98	.....	95.2	2.183	.....	90.0
Mean (b) ♀ parents	15.62	.....	95.2	15.10	.....	102.1	2.375	.....	97.9
R x A	15.54	101.8	94.7	14.99	98.9	101.4	2.355	101.9	97.1
D x A	17.47	104.9	106.5	14.50	97.4	98.0	2.543	102.3	104.8
S x A	19.00	113.2	121.8	14.93	100.2	100.9	2.985	118.0	123.0
T x A	16.28	98.9	98.9	14.41	98.1	97.4	2.349	97.0	96.8
U x A	18.58	107.8	113.2	14.94	98.4	101.0	2.806	107.0	115.7
V x A	17.08	106.2	103.8	14.68	100.4	98.3	2.507	106.2	103.3
W x A	15.26	93.8	93.0	15.54	108.6	105.1	2.383	101.7	98.2
Mean (c) A ♂	17.16	10.45	104.6	14.86	100.3	100.4	2.561	104.9	105.6
R x B	15.62	117.4	95.2	16.65	104.5	112.6	2,606	122.3	107.4
D x B	17.34	118.0	105.7	15.96	101.9	107.9	2.778	120.2	114.3
S x B	16.26	108.9	99.1	16.14	102.9	109.1	2,628	111.8	108.3

Table 3.—Continued.

Inbred or hybrid variety	Acre-yield of roots			Sucrose percentage			Acre-yield of gross sugar		
	Actual yield	As percent of parents	As percent of Syn. Check	Actual reading	As percent of parents	As percent of Syn. Check	Calculated yield	As percent of parents	As percent of Syn. Check
	Tons	Percent	Percent	Percent	Percent	Percent	Tons	Percent	Percent
T x B	16.90	110.1	96.9	15.60	100.8	105.5	2.481	110.6	102.3
U x B	16.79	110.0	102.3	16.70	104.6	112.9	2.813	115.1	116.0
V x B	15.28	103.6	93.1	16.18	105.0	109.4	2.476	113.4	102.0
W x B	16.66	116.5	101.5	15.51	102.8	104.9	2.597	120.0	107.0
Mean (d), B d'	16.26	112.8	99.1	16.11	103.2	106.9	2.625	116.2	108.2
R x Syn. Check	14.43	96.9	87.9	15.62	102.2	105.6	2.257	99.4	93.0
D x Syn. Check	17.15	105.3	104.5	15.39	102.5	104.1	2.641	107.9	108.9
S x Syn. Check	17.64	106.7	107.5	15.57	103.6	105.3	2.748	110.1	113.1
T x Syn. Check	15.92	99.3	97.0	15.73	103.5	106.7	2.515	105.6	103.7
U x Syn. Check	17.42	108.3	106.2	14.08	104.7	108.4	2.902	106.6	119.5
V x Syn. Check	17.40	111.1	106.0	15.20	102.1	102.6	2.660	115.9	110.9
W x Syn. Check	15.15	95.4	92.3	15.00	103.9	101.4	2.288	99.8	94.2
Mean (e), Syn. Check d'	16.44	102.6	100.2	15.51	103.8	104.9	2.562	106.7	105.5
Diff. required for significance, odds 19:1—									
Between individual inbreds or hybrids	1.57	.....	9.6	0.77	.....	5.2	0.303	.....	12.5
Between hybrid and mean of parents	1.38	.....	.....	0.68	.....	.....	0.266	.....	.....
Between means of 7 shown in table	0.60	.....	3.7	0.30	.....	2.0	0.116	.....	4.8

proved root weight or to sucrose percentage or to both, is economically important, depends on the heritable qualities of the parents and their interactions. The comparisons with Synthetic Check throw light on this situation. Whereas the majority of the hybrids do not differ significantly from Synthetic Check in sugar production, a few are significantly better.

Certain individual hybrids are outstanding in sugar production, namely, B' x A, D x A, S x A, U x A, D x B, U x B, S x Synthetic Check, and U x Synthetic Check. B' x A, or U. S. 216 x U. S. 215, is probably superior in sugar production to Synthetic Check, even in the absence of leaf spot. Its superiority rests on its slightly better root yield (4.8 percent) and its better sucrose percentage. The combined result of these factors is a gross-sugar production approaching closely to a significant difference.

Hybrids D x A and D x B are crosses of a highly productive, moderately leaf spot resistant inbred with U. S. 215 and U. S. 216, respectively. Both hybrids are outstanding in performance. The inbred D' shown in table 2, which has the same pedigree as D but with one additional generation of inbreeding, did not duplicate this reaction. In this connection it is interesting to note that genetic material from the same line as D was utilized to produce the variety, SPI 4-6-00, that was included in the 1945 agronomic evaluation tests. The particular cross was between 8-270-0, a progenitor of D, and Improved U. S. 215. 4-6-00 produced 11 percent more sugar per acre than U. S. 215 x 216 taken as the standard *(S)*.

The tests also reveal that Inbreds U and A have excellent potentialities, particularly because of the excellent root weights obtained when these inbreds are used in hybrid combinations. Both inbreds were obtained from European commercial brands but have been reselected and inbred several times. Inbred TJ, selected from Pioneer, is particularly impressive in its performance in that it gave hybrids with A, B, and Synthetic Check, all of which were significantly better sugar producers than Synthetic Check.

In corn investigations, top crosses have been utilized as a means for preliminary appraisal of inbreds with respect to their possible performance in hybrid combinations. The hybrids of Avhich Synthetic Check is the pollen parent may be examined to determine whether top-cross technique applied to sugar beets would give similar indication of potentialities of inbreds. The hybrid D x Synthetic Check, reported in table 2, although not significantly better in root weight than Synthetic Check, is conspicuous among the other hybrids in its yield. The sugar per acre produced by this hybrid also is not significantly above Synthetic Cheek but is. the highest of its group, and

likewise in crosses with A and B the mother strain D is outstanding. Inbred B' probably would not be selected for its performance when pollinated by Synthetic Check, except for the significantly higher sucrose percentage of the hybrid as compared with Synthetic Check. The hybrid is not significantly higher in sugar production.

Inbreds reported in Table 3. that from other considerations were considered outstanding, are D, S, and IT. Five of the six hybrids involving these mother strains and A and B pollen parents are above Synthetic Check in root weight, two significantly so. Five of these hybrids are above Synthetic Check in sucrose percentage, and in three cases the difference is significant. In sugar production, each of the six hybrids is above Synthetic Check, significantly so in four cases. Of the three mother inbreds discussed, S and U are most outstanding as judged by sugar production of the hybrids, S x A, S x B, TT x A, and U x B. Of the seven top crosses shown in table 3, only those having S and U as mother parents are significantly above Synthetic Check in sugar yield. The top cross, D x Synthetic Check, although fairly high, is not particularly outstanding. Using the top-cross technique, only S and U would be positively indicated, certain other inbreds being given only tentative consideration. It would seem, from this limited sampling, that Synthetic Check as a top-cross parent, in case there were many inbreds to evaluate, might prove very effective as a tester.

Summary

Thirty-five sugar beet hybrids obtained by mating 11 inbred strains and 1 open-pollinated variety with U. S. 215, U. S. 216, and Synthetic Cheek as pollen parents were studied for root yield, sucrose percentage, and sugar production under conditions in which leaf spot was not a factor. The inbred strains were relatively high yielding. Other comparisons were made with Synthetic Check, a variety known to be very high in yield when leaf spot is not a factor. As a consequence, relatively few hybrids significantly exceeded, in the attributes measured, the means of parents or Synthetic Check. As a class, however, the hybrids were significantly superior to the parents. The data were based on identified hybrids and were taken in absence of leaf spot. They are interpreted as indicating definitely that heterosis occurs in sugar beels, but that with the higher yielding inbreds, and when comparisons are based on a high yielding variety such as Synthetic Check, relatively few inbreds give outstanding performances. Synthetic Check may be of value as a tester in the application of the top-cross technique to locate the inbreds with best potentialities.

Literature Cited

1. Coons, G. H. Improvement of the Sugar Beet. U. S. Dept. of Agr. Yearbook. 1936:625-56. 1937.

2. Coons, G. H., Dewey Stewart, and J. O. Gaskill. A New Leaf Spot Resistant Beet Variety. Sugar 36(7) :30-3. July 1941.

3. Coons, G. H., Dewey Stewart, *et al.* Tests in 1945 of U. S. 215 x 216, and Other Varieties from Sugar Beet Leaf Spot Resistance Breeding Investigations of the U. S. Department of Agriculture. Proc. Amer. Soc. Sug. Beet Tech. pp._____1946.

4. Keller, Wesley. Inheritance of Some Major Color Types in Beets. Jour. Agr. Res. 52:27-38. 1936.

5. Stewart, Dewey, C. A. Lavis, and G. H. Coons. Hybrid Vigor in Sugar Beets. Jour. Agr. Res. 60 :715-38. 1940.