TOP CROSS TEST.

By the spring of 1939, the beet breeding work of the station had resulted in the accumulation of a considerable number of more or less inbred lines of sugar beets. Some method of eliminating the lines least likely to be of value in any hybridizing program is necessary if such work is to be kept within the limits of time, funds, and land available for the testing of hybrids. After considerable discussion with staff members of the Agronomy Department of the Colorado Experiment Station, it was decided to attempt the adaptation to beet breeding of the top cross test, (so effectively used by the corn breeders). It appeared desirable that the pollen parent should be one not related, closely, with any of the sugar beet lines to be tested and one which would produce hybrids which could be positively identified. Red garden beet appeared to meet these requirements. It was also known that the F_1 of this cross was a vigorous high yielding plant in most cases. Basing of this test on known hybrids is open to the objection that it will probably be impossible to commercially produce 100 percent hybrid beet seed. This objection is at least partially offset by the advantage of getting an accurate check of the crossability of individual lines. It is known that lines exist which are so strongly self fertile that when interplanted with another line very little crossing usually occurs.

Several hundred roots representing over one hundred more or less inbred lines were interplanted with unselected roots of red garden beet in the spring of 1939. Seed yields varied from small amounts to as much as a hundred grams or

more per plant. While most of the inbred lines used appeared to be somewhat homozygous for many characters, it was felt that till more was known of the performance of such hybrids, the tests should be based on the progeny of single plants. The small amount of seed from most of these plants limited the size of any test plots which could be used. Since it has been found that increases in the number of replications is more effective in reducing experimental error than an increase in the size of the plots, it was decided to use single 20 foot rows for this progeny test. A minimum of 25 to 30 grams of seed will suffice for six replications of plots of this size. Slightly over 100 seed lots of this size were available from the 1939 seed crop. In addition about 50 smaller seed lots were used for three replications. Two commercial brands of sugar beets were included as checks. The seed lots were randomized in each replication.

This test was hand planted in late April, but soil moisture was not sufficient for germination till the plots were irrigated May 15. Good stands were secured on most plots. The test was thinned about June 15. Spacing was approximately 12 inches in 20 inch rows. A wire with knots at 12 inch intervals was used as a guide in thinning. Hybrids, identified by the red leaves, were left in all possible cases; even at some sacrifice of uniformity of spacing in a few plots. If no hybrid was available for a space a sugar beet plant was left. Thinned stands on nearly all plots varied between the limits of 18 and 21 plants.

Prior to thinning random counts on one replication indicated that crossing had varied from less than 10 to over 90 percent and that corssability or non crossability tended to be inherent characters of different lines. The importance of obtaining data on the percentage of crossing was not fully appreciated at the time, and this information was not secured on all crosses in 1940.

This test was hand harvested during the period October 10 to 17. Only the red hybrid (known F_1 beets) were harvested. In the cases where part of the stand of a plot consisted of sugar beets, only the hybrids were harvested and the yield calculated from the beets harvested. The following is an example of this adjustment:

Plot No. 336 18 hybrids and 1 sugar beet (not harvested).

The 18 hybrids occupied appriximately 19 feet of row and weighed 36.3 lbs. 36.3 divided by 19 equals 1.91 lb. yield per foot or row, which multiplied by 20 equals 38.2 lbs. yield for plot 336.

Some method of placing the yields of all plots on a common basis was necessary for statistical analysis of the data. This method is simple and appears to have been fairly satisfactory, particularly in the cases where the hybrids occupied about three fourths or more of the plot. There were a few errors in harvesting and the recording of data which resulted in incomplete data for a few plots. A few strains had such a low percentage of crossing that too few hybrids (0 to 3) were available at harvest. These cases of incomplete data were omitted in the statistical analysis.

A summary of this test follows.

1940
TOP CROSS TEST
Fort Collins, Colorado

Summary

Strain No.	Block I, II, III 3 plot average lb. Roots	% Sugar	lb. Gross Sugar	Blocks IV, V, VI 3 plot average lb. Roots	% Sugar	lb. Gross Sugar	Blocks I to VI 6 plot average lb. Roots	% Sugar	lb. Gross Sugar	Rank 1/
891	34.9	7.0	2.45							
892	32.2	7.7	2.47	32.0	9.3	2.95	32.1	8.5	2.71	65
893	31.4	8.6	2.51	35.5	9.0	3.21	33.4	8.8	2.86	56
896*	38.9	8.2	3.17	39.4	8.3	3.27	39.2	8.3	3.22	26
897*	42.5	8.3	3.51	40.9	9.0	3.66	41.7	8.6	3.59	6
898	27.8			31.9	10.0	3.18	29.8			
899	33.9	8.5	2.79							
901*	38.9	8.6	3.41	36.4	10.4	3.74	37.7	9.5	3.58	1
903	34.4	7.4	2.45	33.3	9.8	3.26	33.8	8.6	2.86	56
904	33.1	7.1	2.28	32.4	8.7	2.82	32.8	7.9	2.55	70
905	43.1	7.5	3.21							
907	36.6	8.1	2.86	38.1	8.6	3.24	37.4	8.4	3.05	39
908	35.9	7.4	2.60	40.4	9.0	3.63	38.2	8.2	3.11	34
909	35.9	7.1	2.49	36.0	9.1	3.19	36.0	8.1	2.84	58
914*	46.2	8.1	3.73	40.1	8.9	3.59	43.2	8.5	3.66	4
915		9.2		35.8	10.5	3.76		9.8		
916		8.4		39.4	9.3	3.66		8.9		
917	39.5	7.7	3.04	37.0	8.9	3.17	38.2	8.3	3.10	35
918*	40.7	7.3	2.94	41.1	9.2	3.78	40.9	8.2	3.36	16
919*	41.1	7.8	3.17	45.2	8.2	3.69	43.2	8.0	3.43	13
920	29.5	8.5	2.47							
925	30.8	7.7	2.31							
927	34.3	8.2	2.69							
930	34.9	7.2	2.38	35.6	8.7	3.11	35.2	8.0	2.74	63
931	35.3	7.6	2.58	33.8	9.4	3.15	34.5	8.5	2.87	55
939	31.6	8.6	2.64	36.9	9.4	3.46	34.2	9.0	3.05	39
940	37.9	7.5	2.81	42.4	8.2	3.37	40.1	7.8	3.09	36
940	38.7	7.8	3.01							
944	32.6	8.3	2.61	36.4	9.5	3.45	34.5	8.9	3.03	41
945	3311	9.3	3.05	34.4	9.8	3.33	33.8	9.5	3.19	28
948	38.5	6.8	2.49	34.7	9.3	3.21	36.6	8.1	2.85	57
949	32.9	8.9	2.84	34.7	10.3	3.58	33.8	9.6	3.21	27
950	33.8	8.6	2.80	37.1	10.1	3.76	35.5	9.4	3.28	21
952	32.7	7.9	2.48	39.2	9.4	3.67	36.0	8.6	3.08	37
952	36.3	8.7	2.99	31.1	9.9	3.08	33.7	9.3	3.04	40

954	37.2	7.5	2.78	39.1	8.8	3.39	38.1	8.2	3.08	37
955	34.7	7.9	2.74							
963*	35.5	8.5	2.93	39.2	9.7	3.73	37.3	9.1	3.33	19
964*	41.2	6.8	2.74	42.0	9.0	3.76	41.6	7.9	3.25	23
965	32.1	8.7	2.76	36.7	9.5	3.46	34.4	9.1	3.11	34
966	28.9	9.0	2.55	34.1	9.8	3.36	31.5	9.4	2.95	48
967*	38.3	7.8	2.93	41.7	9.3	3.85	40.0	8.6	3.39	15
968	33.6	8.9	2.86	36.8	9.6	3.52	35.2	9.2	3.19	28
971*	47.8	6.5	3.11	39.6	8.6	3.36	43.7	7.5	3.23	25
973	36.0	7.4	2.43							
977*	46.5	6.3	2.95	39.5	9.8	3.86	43.0	8.1	3.40	14
978*	35.7	9.0	3.16	43.5	8.9	3.82	39.6	9.0	3.49	11
979	40.9	8.9	3.63							
980	28.3	7.6	2.03	29.4	9.6	2.78	28.9	8.6	2.40	73
981	34.8	9.2	3.11	35.2	9.4	3.31	35.0	9.3	3.21	27
986*	41.0	7.9	3.21	40.6	8.9	3.56	40.8	8.4	3.39	15
990	35.5	7.7	2.57	32.8	8.6	2.76	34.2	8.1	2.67	66
991	31.6	7.3	2.22	33.9	9.6	3.23	32.7	8.4	2 73	64
992*	36.4	7.9	2.79	37.6	10.0	3.72	37.0	9.0	3.26	22
993	41.1	6.1	2.51							
994	23.5	8.6	1.98							
997	39.3	5.9	2.34							
998	32.1	6.8	2.07	37.9	8.3	3.11	35.0	7.6	2.59	69
1000	39.7	7.5	2.89	40.7	8.3	3.36	40.2	7.9	3.12	33
1001	40.5	6.8	2.69	42.4	7.9	3.28	41.4	7.3	2.98	45
1002*	35.3	7.3	2.52	44.2	8.6	3.80	39.8	8.0	3.16	30
1004	37.1	7.8	2.73	40.6	8.3	3.38	38.9	8.0	3 05	39
1008	39.0	7.8	2.96							
1009	29.9	8.1	2.32							
1010	27.0	8.3	2.16	35.6	9.6	3.39	31.3	8.9	2.78	61
1016	31.7	8.3	2.56	30.0	9.9	2.95	30.8	9.1	2.75	62
1019	27.1	7.2	1.99	36.8	7 7	2.78	32.0	7.4	2.38	74
1020*	37.2	7.8	2.80	40.9	8.6	3.52	39.1	8.2	3.16	30
1021	32.1	7.0	2.23	32.2	9.4	2.97	32.1	8.2	2.60	68
1022	32.5	7.4	2.44							
1923	26.7	8.7	2.27	30.2	8.4	2.55	28.4	8.6	2.41	72
1028	35.1	8.4	2.96	36.6	9.3	3.41	35.8	8.9	3.19	28
1029	31.5	8.5	2.62							
1030	36.1	7.1	2.54	38.5	8.5	3.26	37.3	7.8	2.90	52
1031	38.3	8.1	3.11	33.6	10.2	3.41	36.0	9.2	3.26	22
1032	34.4	8.5	2.84	36.2	8.2	2.96	35.3	8.4	2.90	52
1034	34.4	7.2	2.43	37.7	8.6	3.24	36.0	7.9	2.83	59
1040	32.3	8.1	2.58							
1042	40.7	7.0	2.79	33.7	9.2	3.05	37.2	8.1	2.92	51

1043*	38.4	9.3	3.54	37.2	9.3	3.48	37.8	9.3	3.51	9
1044	31.7	8.1	2.51							
1046	31.5	8.0	2.55	32.3	9.9	3.18	31.9	8.9	2.86	56
1050	34.2	7.8	2.62							
1052*	38.0	8.8	3.31	38.9	9.7	3.72	38.4	9.2	3.52	8
1053	29.5	8.7	2.49	33.4	9.0	3.02	31.4	8.8	2.75	62
1054	29.8	8.4	2.44	32.6	10.9	3.53	31.2	9.6	2.97	46
1057	36.6	8.3	3.01	35.2	9.7	3.32	35.9	9.0	3.17	29
1058*	39.7	7.6	3.04	38.1	9.1	3.46	38.9	8.4	3.25	23
1064	33.9	7.1	2.33	36.1	10.0	3.58	35.0	8.6	2.96	47
1068	35.9	8.2	2.91							
1069	34.2	8.3	2.67	36.7	8.8	3.18	35.4	8.5	2.92	51
1070	28.3	7.1	1.94	36.6	8.8	3.16	32.4	8.0	2.55	70
1076	30.9	7.7	2.33	32.2	8.4	2.66	31.6	8.0	2.50	71
1077*	38.2	7.7	2.93	34.4	10.1	3.48	36.3	8.9	3.21	27
1088	33.8	7.9	2.59							
1089	27.3	7.7	2.10							
1090	31.6	7.9	2.41							
1094	36.6	7.9	2.74							
1096	34.5	8.3	2.79							
1100	35.9	7.6	2.72							
1104	35.7	7.7	2.71							
1111	33.2	7.9	2.59	34.5	9.8	3.35	33.8	8.8	2.97	46
1112	35.4	8.9	3.15	32.6	10.7	3.44	34.0	9.8	3.29	20
1114	30.6	8 5	2.55	36.3	8.8	3.20	33.4	8.6	2.87	55
1115	31.8	7.8	2.35	34.8	9.9	3.42	33.3	8.8	2.89	53
1116	30.9	7.5	2.14	38.1	8.2	3.12	34.5	7.9	2.63	67
1117	34.6	7.8	2.64	33.3	9.6	3.12	34.0	8.7	2.88	54
1118	37.3	6.7	2.47	35.2	9.4	3.27	36.2	860	2.87	55
1119	31.3	8.4	2.59	32.7	9.7	3.11	32.0	9.0	2.85	57
1125	35.9	8.7	3.10	42.0	10.2	4.28	39.0	9.9	3.69	2
1126	33.4	9.4	3.06	35.8	11.2	3.94	34.6	10.5	3.50	10
1127	36.9	8.4	3.08	31.2	10.5	3.26	34.0	9.9	3.17	29
1128*	44.0	7.6	3.32	41.3	9.6	3.96	42.6	8.6	3.64	5
1130	32.0	8.8	2.79	33.4	10.7	3.50	32.7	9.8	3.14	31
1131	31.0	9.2	2.81	32.0	10.6	3.34	31.5	9.9	3.08	37
1132	31.8	8.6	2.72	35.0	8.9	3.08	33.4	8.8	2.90	52
1133*	40.4	7.3	2.94	39.1	10.3	4.02	39.7	8.8	3.48	12
1134	28.3	8.7	2.38							
1135	34.9	8.5	2.97							
1136	33.6	7.8	2.41	33.5	10.9	3.61	33.5	9.4	3.01	43
1137	34.4	8.5	2.92	33.2	9.6	3.18	33.8	9.0	3.05	39
1138	33.3	8.3	2.74	36.1	11.1	3.99	34.7	9.7	3.36	16
1139	3[illegible].3	9.6	3.44							
1141*	39.2	8.0	3.14	36.1	9.5	3.35	37.6	8.8	3.24	24
1145	32.5	9.0	2.90							
1148	32.5	8.4	2.63	31.6	10.3	3.24	32.0	9.3	2.93	50
1149	[illegible]	[illegible]	[illegible]	[illegible]						

1149	34.8	8.3	2.91	34.3	10.6	3.65	3486	9.8	3.28	21
1150	39.0	7.2	2.71							
1151	32.1	7.9	2.45	40.5	9.0	3.57	36.3	8.4	3.01	43
1152	31.4	8.6	2.62	36.8	10.0	3.62	34.1	9.3	3.13	32
1153*	45.0	7.3	3.29	35.3	8.7	3.00	40.1	8.0	3.14	31
1154	38.9	7.6	2.93							
1155	35.1	7.2	2.44	37.2	9.9	3.69	36.2	8.6	3.06	38
1158	33.8	9.4	3.14							
1161	36.1	7.1	2.49							
1163	35.7	7.7	2.75	31.0	10.2	3.13	33.2	9.0	2.94	49
1164	34.5	7.8	2.70							
1166	37.7	8.3	3.06	30.0	10.0	2.94	33.8	9.2	3.00	44
1168	25.0	9.5	2.30							
1170	33.7	8.4	2.69							
1171	28.6	8.1	2.20	30.0	11.0	3.29	29.3	9.5	2.74	63
1172	34.6	8.6	2.94	30.8	9.5	2.89	32.7	9.0	2.92	51
1173	38.7	9.2	3.58							
1174	35.5	8.6	3.04							
1175*	36.5	8.8	3.13	38.7	9.2	3.56	37.6	9.0	3.34	18
1181	36.9	6.6	2.42							
1184*	36.9	9.1	3.35	43.0	9.4	4.01	40.0	9.3	3.68	3
1185	36.2	7.2	2.62	35.6	10.0	3.49	36.0	8.6	3.05	39
1186	33.8	8.2	2.74	35.6	9.4	3.30	34.7	8.8	3.02	42
1187*	38.7	7.2	2.77	41.2	8.8	3.58	40.0	8.0	3.17	29
1189	30.5	8.3	2.46							
1196	34.7	8.4	2.84							
1201	33.1	8.0	2.57							
1202	33.0	8.9	2.95							
1204*	34.0	8.5	2.86	39.6	9.8	3.84	36.8	9.1	3.35	17
1206	39.2	7.9	3.03							
1207	34.2	8.5	2.80							
F. Fol	21.5	10.6	2.28	26.8	12.4	3.30	24.2	11.5	2.79	60
G. West.	29.3	11.0	3.23	31.8	13.2	4.19	30.5	12.1	3171	1
Mean	34.84	8.05	2.74	36.22	9.48	3.39	35.62	8.76	3.07	
F	2.20*	2.26*	2.05*	1.63*	2.47*	1.14**	3117*	3.71*	2.15*	
S.E.of M.	2.89	.52	.25	2.88	.55	.31	2.01	.38	.20	
2xS.E.of Diff.	8.17	1.47	.70	8.13	1.57	.87	5.68	1.08	.57	
S.E.ofM in % of Mean	8.29	6.45	9.01	7.94	5.84	9.07	5.64	4.35	6.54	

* F exceeds 1% point.

** F approximates 5% point.

1/ Rank in pounds of gross sugar per plot for the average of six replications.

Discussion.

The test was not planned in such a way that any very definite conclusions can be reached regarding the performance of sister lines. In general, there is a trend for the progeny of a high sugar mother to also be slightly higher in percent sucrose. This trend is by no means uniform. There appears to be little relation between the weight of the seed bearing mother beet and the yield of the progeny in most cases. Some form of a split plot experimental design should give much better comparisons of such lines. A few typical cases of the performance of sister lines are given in the following table with data on the seed bearing mother beet. Groups of sister lines are separated by a double space.

Strain No.	Pedigree.	Mother root. Wt.	Mother root. %Sucr.	Hybrid Progeny (Ave. 6 Rep.) Plot Yld. lbs. Roots	Gross Sug.	% Sucr.	Rank 1/
903.	ss	1.6	14.9	33.8	2.86	8.6	56
904.	"	3.4	13.2	32.8	2.55	7.9	70
907.	sg	2.4	10.1	37.4	3.05	8.4	39
908.		2.6	12.6	38.4	3.11	8.2	34
909.		1.8	14.5	36.0	2.84	8.1	58
930.	ssss	3.2	10.7	35.2	2.74	8.0	63
931.		2.1	12.6	34.5	2.87	8.5	55
944.	ss	2.8	12.1	34.5	3.03	8.9	41
945.		2.2	16.0	33.8	3.19	9.5	28
948.	ssss	4.0	12.4	36.6	2.85	8.1	57
949.		1.7	15.8	33.8	3.21	9.6	27
950.	ssss	3.9	11.5	35.5	3.28	9.4	21
951.		1.8	14.7	36.0	3.08	8.6	37
967.	sss	1.7	14.7	40.0	3.39	8.6	15
968.		3.0	14.7	35.2	3.19	9.2	28

1/ Rank in gross sugar, 107 strains, (6 replication average)
Pedigree: s indicates one generation of selfing by isolation.
g " " " " sib pol ination, usually a few roots.

The yield of the Great Western commercial check was used as the basis of evaluation of the performance of the hybrids. Under the conditions of this test, three replications appear to be inadequate and only the strains included in the six replications were considered for statistical consideration of yields. A few of the better appearing lines from the three replications will be retained for further test and the poorer ones, probably, will be abbitrarily dropped.

On the basis of the performance in this test, 29 strains exceeded the check in yield of beets by more than twice the standard error of a difference and were not exceeded by the check in yield of gross sugar by as much as twice the standard error of a difference. These strains are makked in the summary by a * following the strain number; e g 896*. The number of inbred lines represented in this group is only 25 since four pairs of sister lines are included. The above 29 strains all fell within the first 31 in rank of gross sugar. Eleven other strains, one of them not strickly an inbred line, also fell within this group, but failed to meet one or the other of the above requirements. It is believed that on the basis of statistical analysis and observations, over half of the inbred lines included in this top cross test may be dropped from further work with little danger of discarding valuable breeding material.

From the results of this test, it appears that the use of plots as small as single rows 20 feet in length if replicated six or more times, may be used in the evaluation of strains of beets when the amount of seed is

limited. Such plots probably will not lead to high precision in the measurement of small differences, but promise to be valuable in the elimination of the poorest lines with a minimum of expense.