Possibilities for Improving Storage-Rot Resistance of Sugar Beets Through Breeding[1]

JOHN O. GASKILL[2]

Rotting of sugar beets, *Beta vulgaris* L., in storage piles between time of harvest and processing is an extremely important problem in most sugar beet regions in the United States. The seriousness of this problem and factors related to its control have been discussed by various investigators—e.g. Larmer (3)[3], Gaskill (1, 2), and others—and will not be reviewed in this paper.

Experimental work was begun at Fort Collins, Colorado, in the spring of 1948 in order to investigate the possibility of attacking this problem effectively by breeding for storage rot resistance. The work performed thus far includes comparison of uninoculated field-grown roots of various strains for keeping quality and preliminary studies pertaining to resistance of strains and of individual roots as measured by rate of rotting following artificial inoculation. Definite conclusions regarding the effectiveness of the selection techniques used must await the outcome of further work, especially progeny tests, and consequently this paper is presented merely as a progress report.

Comparison of Beet Strains by Means of Uninoculated Roots

Thirty strains of *B. vulgaris*, including sugar beets, garden beets, 1 mangel variety, and several hybrids (sugar- x garden beet and mangel) were grown in 4-row, 29-foot plots in a field near Fort Collins, Colorado, in 1948. Randomized-block design was used, 3 blocks receiving a moderate application of a complete fertilizer and 3 blocks receiving no fertilizer. Data from another experiment indicated that this field was moderately deficient in nitrogen and slightly deficient in available phosphorus. The crop was planted on May 1, handled in the usual manner throughout the season, and harvested September 29-October 1. Seedling disease and certain mechanical difficulties resulted in thin stands in scattered plots, and consequently harvest was limited entirely to competitive beets—i.e., plants having approximately normal competition. One strain was deleted entirely because of poor stand **resulting** from low germination.

For storage comparisons, two 25-beet samples were dug by hand in each plot, where stand was adequate, and topped as shown in Figure 1, care

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[2] Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, Fort Collins, Colorado. Acknowledgment is made to the Botany and Plant Pathology Section of the Colorado Agricultural Experiment Station and to the Beet Sugar Development Foundation for facilities used in connection with these investigations, and to Dr. L. H. Coons of the Division of Sugar Plant Investigations for helpful suggestions in connection with the planning of the experiments.

[3] Numbers in parentheses refer to literature cited.

Figure 1. Interior and exterior views of 4 sugar beet roots after approximately $4^{1/2}$ months' storage at 45° F.: left, 2 roots of strain 5; right, 2 roots of strain 7; attempt made to pick representative roots from comparable samples.

being taken to avoid spade injury and topping-knife hook injury. Where stand was poor, sample size was reduced to a minimum of 10 roots. After being washed and drained, the 2 samples from each plot were placed in shallow wooden boxes and stored in insulated rooms for approximately 3 months at 65° F., and $4^{1/2}$ months at 45° F., respectively. The air in each room was circulated constantly by means of fans, continuous forced ventilation was provided, and relative humidity was maintained at a level high enough to prevent excessive evaporative loss in weight of healthy roots. The latter was accomplished for each room by means of wet Sphagnum moss on floors and *on* a part of the wall surface and by passing a stream of air over hot water.

At the end of storage the percentage of rot in each sample was determined by separating and weighing the rotted and healthy tissue. There was relatively little overall difference between fertilized and unfertilized replications, in percentage rot, and interaction between strains and fertilizer treatments appeared to be unimportant. Consequently the data from all replications were pooled as shown in Table 1. These averages show highly significant differences between sugar-beet strains, in percentage rot, with significant positive correlation between 65° and 45° results. It is of interest to note the contrast between certain groups of strains—e.g., those descending from the 1833 source (strains 4, 5, and 6) as compared with those derived from 1846 (strains 7, 8, 9, and 10) . The exceptionally low rot percentages obtained for the 2 garden beet varieties (strains 26 and 27) are noteworthy and suggest the possibility of using that branch of the species as **a** source of resistance.

Inoculation Studies ,

In March, 1949, approximately 400 mother beets[4] of strain 21 which had been stored since fall in the 45° room previously described were inoculated for the purpose of selecting storage-rot-resistant individuals. Inoculum was prepared by chopping and machine blending healthy and rotted tissue from a number of partially rotted sugar beets which had been similarly stored. A small amount of water was added to facilitate blending. An area

[4] Full-sized roots with crowns; suitable for growing seed.

Table 1.—Comparison of keeping qualities of strains of beets stored **approximately** 3 **months** at 65° **F. and** $4^{1/2}$ months **at** 45° F.; results given as 6-plot averages. **Fort Collins,** Colorado, 1948-49.

Strain desig-nation used in text	Sugar Plant Invest. seed No.	Description and Source[a]	Final stand per 100' Number	Wt. of rotted tissue at end of storage 65° F.[b] Percent	45° F. Percent
1	Acc. 5072	U.S. 22/3; curly-top-resistant commercial variety	96	20.1	6.9
2	Acc. 1099	G.W. 59; Great Western Sugar Co. commercial variety	91	13.9	6.0[d]
3	Acc. 1098	U.S. 215 x 216/3; leaf-spot resistant commercial variety	99	15.4	9.1
4	451-0	Improved U.S. 216; inbred; 1833	93	9.2	9.0
5	I-16-0	U.S. 216; inbred; 1835	96	14.2	5.6
6	451047-0	Tetraploid U.S. 216, developed by F. A. Abegg[c] from diploid I-16-0; 1853	78	5.9[d]	3.6[d]
7	471003-0	U.S. 225; inbred; 1846	80	28.1	11.7[d]
8	4-1005-0	U.S. 215; inbred; 1846	74	38.2[d]	....
9	461020-0	Improved U.S. 215; inbred; 1846	74	29.5[d]	23.4[d]
10	461015-0	Tetraploid U.S. 215, developed by F. A. Abegg[c] from diploid U.S. 215; 1846	77	23.1[d]	6.8[d]
11	455-0	Unnamed European strain improved by mass-selection	99	11.3[d]	.....
12	0-13-0	Inbred; 10545	83	10.4	2.9[d]
13	471002-0	Inbred; La Royale	94	19.0[d]	6.1
14	1-12-0	Italian strain improved by mass selection; R-581	96	19.7	5.1
15	462-0	Inbred; Old Type	57	....	....
16	4-4-0	Inbred; 2140	86	14.0	5.2
17	471001-0	Inbred; Pioneer	84	28.2[d]	4.4[d]
18	461004-0	Inbred; G.W. 49	59	7.0[d]	....
19	9-290-0	Inbred; 2092	73	13.7[d]	4.9[d]
20	4-1048-0	Inbred; 1846 x 1833	82	35.2	12.2[d]
21	471004-0	U.S. 226 (white-base synthetic variety)	93	10.9	3.3
22	451057-0	Synthetic variety involving a trace of *B. maritima* ancestry	78	22.6[d]	6.2[d]
23	Acc. 1080	Mammoth Long Red mangel	88	31.0	7.3[d]
24	4-1026-0	Unselected increase of Old Type	76	22.3[d]	10.1[d]
25[e]	4-1839-02	F_1; Old Type x Mam. Long Red Mangel	93	19.5	5.2
26	Acc. 1078	Improved Blood garden beet	79	6.4	1.7[d]
27	Acc. 1102	Crosby's Egyptian garden beet	83	9.2[d]	3.3[d]
28	451064-0	Mass increase of the cross, U.S. 216 x (sugar x garden beet)	92	12.5	4.1
29	Acc. 1103	G. W. Deming[a] No. 1945-309; produced from a cross of U.S. 215 x garden beet by 3 generations of mass selection for high root weight and high sucrose percentage	98	22.2[d]	4.4
30	Acc. 1104	G. W. Deming[a] No. 1945-307; 3 generations of low-weight, low-sucrose selection from above cross	82	7.0[d]	2.6[d]
General mean				17.42	6.57
L. S. D. (5-percent point)				11.3	6.4

Correlation of results for two temperatures (strain 8, 11, 15, and 18 omitted):

r	0.469
t	2.602
P	<0.02

[a] Strains are of sugar beet origin except as otherwise indicated. The term "inbred" indicates at least one generation of selfing.

[b] Roots went into storage during the first week of October, approximately. Rot weighings for the 65° room were made for two replications on December 9, 1948, and for the other four replications during the period, January 3-6, 1949.

[c] Formerly Geneticist, Division of Sugar Plant Investigations.

[d] Only known F_1 roots, identified by pink or red root color, were used for storage comparisons.

[e] Agronomist, Division of Sugar Plant Investigations.

[1 2 3 5] Because of missing sample or samples (generally due to inadequate stand), one, two, or three "missing-plot" values, respectively, were estimated for the indicated strain and storage temperature. Where more than three plot values were missing for a given strain and temperature, no rot percentage is shown.

of about 2 to 3 square inches on one side of each root was scraped with an ordinary vegetable grater, approximately 1 teaspoonful of inoculum was placed on the injured surface, and storage was continued under the same conditions. Five weeks after inoculation the roots were found to differ greatly in depth of rotted tissue beneath the inoculated area (Figure 2). One hundred nine of the more resistant-appearing individuals were transplanted in the field in a single group and allowed to interpollinate. Progenies of surviving plants are to be evaluated for storage-rot resistance in future tests.

A preliminary inoculation experiment was conducted in December and

Figure 2. Four mother beet roots of strain 21 after wound inoculation with composite rot inoculum and incubation for 5 weeks at 45° F. Note variation in depth of rotted tissue (top of freshly cut section outlined with chalk).

January, 1949-50, partly for the purpose of comparing two contrasting strains listed in Table 1 and partly to study methods of evaluating the resistance of individual roots by pure-culture technique. Twenty-two selected mother beets of each strain which had been taken from two comparable field plots in October, 1949, were cut in half longitudinally. One-half of each root was saved for possible seed production. Crown and tail portions of the other half were removed and the remaining piece was inoculated with blended potato-dextrose agar inoculum of a virulent culture of *Phoma betae* Frank which had been isolated from a sugar beet storage-rot specimen.

Two methods of inoculation were used for each root piece, as follows: (1) A portion of the exterior of the root was peeled with an ordinary vegetable peeler, removing one layer about 1 mm. in thickness, and one drop of the semi-fluid inoculum was applied to the injured surface in each of 2 places; and (2) a round plug about 1/2 inch long was removed from the outer part of the root, inoculum was inserted in the bottom of **the** hole.

Table 2.—Rate of rotting in sugar beet roots inoculated with *Phoma betae* and held at 45° F. for 35 days. Fort CoUins, Colorado, 1949-50.

Strain[a] No.	Root No.	Depth of discolored tissue: Peeled-surface[b] inoculation	Depth of discolored tissue: Plug[c] inoculation	Average
		Mm.	Mm.	Mm.
	1	6.0	6.0	6.00
	2	4.3	4.0	4.15
	3	6.0	7.5	6.75
	4	2.5	5.0	3.75
	5	8.3	8.5	8.40
	6	3.0	5.5	4.25
	7	6.0	7.0	6.50
	8	3.8	7.5	5.65
	9	10.5	13.0	11.75
	10	6.3	10.5	8.40
	11	6.0	8.0	7.00
	12	3.5	3.0	3.25
	13	5.5	7.5	6.50
	14	2.3	5.0	3.65
	15	6.5	4.5	5.50
	16	3.5	4.5	4.00
	17	4.3	7.5	5.90
	18	6.3	7.5	6.90
	19	6.3	6.5	6.40
	20	1.0	6.0	3.50
	21	7.0	8.0	7.50
	22	4.3	7.0	5.65
	Aver.	5.15	6.80	5.97
	1	2.8	4.5	3.65
	2	2.3	4.0	3.15
	3	3.5	3.5	3.50
	4	2.3	4.5	3.40
	5	7.0	7.0	7.00
	6	2.3	5.0	3.65
	7	2.5	3.0	2.75
	8	1.5	14.0	7.75
	9	6.5	6.0	6.25
	10	0.5	0.5	2.50
	11	4.0	5.0	4.50
	12	2-0	5.0	3.50
	13	2.0	2.5	2.25
				7.75
				9.25
	19			9.00
	20			3.65

Correlation of surface and plug inoculation results: 0.574
4.543
<0.01

L. S. D. (5-percent point) for individual roots 3.33
L. S. D. (5-percent point) for means of strains 0.71

[a] Strains described in Table 1.
[b] Each value given is an average obtained from two inoculations.
[c] Each value is an average of two measurements made in opposite directions, longitudinally, from one inoculation.

and the plug was replaced and sealed with paraffin. Care was taken to use uniform quantities of inoculum for each type of inoculation. The inoculated pieces were suspended over a free water surface in loosely covered galvanized-iron containers in which temperature was 45° F. and relative humidity practically 100 percent. After 35 days, the depth of rotted tissue was measured, radial penetration being recorded for the peeled-surface inoculations and longitudinal penetration for the plug inoculations.

The results of this experiment are summarizd in Table 2. Longitudinal penetration, from plug inoculations, was definitely faster on the whole than penetration from peeled-surface inoculations. However, since positive correlation between the two sets of measurements was highly significant, the average column (Table 2) may be used for comparison of strains and of individual roots. The average rate of rotting for the roots of strain 21 was significantly lower than that obtained for strain 7, thus agreeing with the results obtained from uninoculated roots in an earlier experiment (Table 1) . The occurrence of highly significant differences between roots of each strain tends to substantiate the results of another experiment, previously discussed and illustrated in figure 2. Although conclusions as to the extent to which such individual root differences are inherited must await the results of progeny tests, these results, together with the strain differences shown in both tables, seem to justify the tentative conclusion that improvement in keeping quality of sugar beets can be expected from a program of selection and breeding for storage-rot resistance.

Summary

Keeping qualities of samples of uninoculated roots of 29 strains of beets, including one mangel and two varieties of garden beets, were compared in a replicated experiment under 65° F. and 45° F. storage conditions. At the end of storage, certain sugar beet strains differed very significantly in percentage of rotted tissue, and both garden beet varieties were quite low in that respect. Relative strain performance at the two temperatures showed significant, positive correlation.

Two of the 29 strains which differed considerably in percentage rot were compared in a later experiment by means of roots inoculated with *Phoma betae* and held at 45° F. for 5 weeks. The two strains differed significantly in average rate of rotting, the results agreeing with those obtained from the earlier experiment, and a number of individual differences between roots, within each strain, were highly significant. Approximately 400 mother beets of the more resistant of these two strains were inoculated with composite storage-rot inoculum and compared after incubation for five weeks at 45° F. The roots differed greatly in rate of rotting, and the more resistant ones were brought to seed for the purpose of progeny testing.

The results reported seem to justify the tentative conclusion that breeding for storage-rot resistance in sugar beets should be advantageous.

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