

Progress in Breeding Sugar Beets for Resistance to *Aphanomyces* Root Rot

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BREEDING SUGAR BEETS for resistance to *Aphanomyces cochlioides* (drechs) has been carried on since 1942 in the southern Minnesota-northern Iowa beet-growing area by the American Crystal Sugar Company (1).² In the first years of this work very little progress was made, but in 1945 marked differences in resistance were observed between several open-pollinated plant progenies of the American No. 1 variety. In southern Minnesota that year, a 1/2-acre area of sugar beets severely infested with the disease produced 417 roots, many of which were very small and misshapen. From these roots, 71 open-pollinated plant progenies were obtained and tested in 1946 under medium-severe disease conditions at the South East Experiment Station, Waseca, Minnesota, and in four other locations where the disease was less severe or absent. The 71 progenies showed varying degrees of resistance in the Waseca, Minnesota, test; and 20 of the most resistant progenies of the 71 were selected for seed production and field test in 1947.

The results obtained from the roots of these 20 (1946) progenies in the 1947 tests are given in this report, together with data on the 1947 selections made from these resistant lines.

Experimental Procedure

There were 249 beets selected from the best 20 lines (or progenies) of the 71 in test in southern Minnesota in 1946, and these were shipped to Rocky Ford, Colorado, in December 1946, to be replanted in the Company's greenhouses for winter seed production. All beets from the 20 lines were replanted, there being no discard of beets for other characters prior to replanting. At flowering time, each plant was self-pollinated, using one No. 8 Kraft bag, and in addition, one No. 8 Kraft bag was placed on each plant for sib-pollination of plants *within* the line progenies by "bag switching" technique. All open-pollinated seed was harvested by individual plant as in previous years.

All seedlots were harvested in late April, and in time for test plantings in the 1947 summer season. Of the 249 roots planted in the greenhouses, 72 produced adequate quantities of open-pollinated seed to plant at least 240 feet of beet row at a planting rate of 7 seeds per foot, and an additional 123 produced seed adequate to plant at least 80 feet of row at this planting rate. One hundred plants produced inbred seed in amounts suf-

¹Plant Breeder and Plant Pathologist, respectively, American Crystal Sugar Company, Rocky Ford, Colorado.

²The numbers in parentheses refer to literature cited.

ficient to plant 1 to 25 hills; and 38 sibbed progenies were obtained in amounts adequate to plant 15 to 75 hills.

After all seedlots were made up, surplus seed of the 195 open-pollinated progenies was bulked into two lots, 6-404a and 6-404b, the former being a bulk lot judged to be the best of the selections. This lot was planted in a strip test in comparison with the three check varieties, U. S. 216, 1-9-00³, and American No. 3, on the test field at Mason City, Iowa.

Plan of 1947 Tests

All the 100 inbred seedlots and the 38 sibbed seedlots were planted in late May at Rocky Ford, Colorado, in nursery plots. The 195 open-pollinated plant progenies were planted in southern Minnesota and northern Iowa in 6 test fields. The locations of the test fields and the root rot infestation which developed in these fields were as follows:

Field A—extremely heavy infestation, South East Experiment Station, Waseca, Minnesota

Field B—moderate infestation, J. Johnson Farm, Mankato, Minnesota

Field C—traces of disease, August Seys Farm, Mankato, Minnesota

Field D—traces of disease, S. Poncin Farm, St. Peter, Minnesota

Field E—no infestation, P. Ritz Farm, St. Peter, Minnesota

Field F—heavy infestation, G. Sprole Farm, Mason City, Iowa

In each test field the seed progenies were planted in 2 replications of plots 20 feet long by 1 row wide. The varieties, U. S. 216, 1-9-00, and American No. 3, which were used as checks, were planted in adjacent single-row strips through the field, there being at least 11 or 12 rows of resistant progenies between each 3-row strip of checks. Alleys 3 feet wide crossed the test fields at 20-foot lengths, i. e.—at the end of the plots. Tests A and F included all 195 seed progenies, and in tests B, C, D, and E, the 72 high seed-producing lines of the 195 were planted. All 20-foot row plantings were made with 140 seedballs, or 7 seedballs per foot of row. No seed treatment was used on seed in any of the plantings.

Laboratory germination tests were run on each of the seedlots produced by the 195 lines. Sixteen of the lines were lower than 70 percent in germination, but were considered to be high enough to produce adequate stands at the planting rate planned. The other 179 line seedlots ranged up to 100 percent germination. All lines produced sufficient stand, in all tests, for a thinned stand of one beet per foot of field row.

Experimental Results

Plot Tests.—The data obtained from the Waseca Experiment Station in 1946 on the 71 lines tested that year, indicated substantial improvement over all check varieties, not only from notes on vigor of foliage and percentage stand, but also on actual weight of beets harvested per plot. A check on this 1946 result was obtained from the strip test plantings of 6-404a (which,

³1-9-00 is a USDA selection known to be extremely susceptible to *Aphanomyces* root rot.

as described above, was a seed increase from part of the 1946 selected roots) and the three check varieties, U. S. 216, 1-9-00 and American No. 3. The complete results of this test are given in table 1.

Table 1.—Yield of 6-404a in comparison with the commercial varieties No. US 216, American No. 3, and the Susceptible Check 1-9-00, Mason City, Iowa, 1947.

Block No.	Yield in Tons per Acre			
	U S 216	1-9-00	American No. 3	6-404a
1	1.634	0.000	.653	3.928
2	1.143	0.000	.326	7.024
3	1.143	.653	1.960	8.984
4	2.614	1.470	2.450	8.167
5	0.000	0.000	1.306	9.905
6	3.594	.490	3.267	9.964
Average	1.69	.44	1.66	8.00
Average of three check varieties		1.60		
Total number of marketable beets per acre at harvest	5,009	1,307	4,574	15,464

In this test, a strip of 5 rows wide and 120 feet long was harvested in six 20-foot blocks; 6-404a was a 2-row strip, and the three adjacent check varieties were single-row strips. All beets less than .33 pound were considered non-marketable.

Selection Results.—The severity of the disease in the test areas in 1947 did not follow quite the same pattern as in 1946. Fields C, D, and E, were found to be practically free of the disease, and therefore could not be used for critical selection purposes. Field B, in which moderate infestation occurred in 1946, had a similar amount of infestation in 1947, but this test area, due to cultural difficulties, was so uneven in stand that it was considered advisable not to select in this field. At Mason City (field F), the disease developed in similar fashion to that of the Waseca test in 1946, having a severe amount of damping off after emergence, and with continuing damage to remaining plants until early August when a drought occurred which reduced damage. At Waseca, an area adjacent to the one used for the 1946 replicated progeny test was selected in 1947. This area proved to be much more severely infested with the *Aphanomyces* rot than the 1946 test area. Selection for increased resistance in 1947 was, therefore, confined to the Mason City, Iowa, and the Waseca, Minnesota, areas (fields A and F).

In early August, vigor of foliage notes, as well as stand counts, were taken on all plots of progeny lines and check varieties at each of the two locations. The Waseca test was found to be so severely damaged that differences in resistance between the plant lines was very small. At Mason City, however, differences in both vigor of growth and surviving stand were observable between lines, and generally good agreement between replications of these lines for stand and vigor was obtained. Further, 13 progenies which were best at Waseca were likewise in the highest category for foliage vigor and percentage stand at Mason City.

Since the Mason City, Iowa, test, considered as medium severe, showed the greatest differences in resistance between lines, plans were made to make the largest selection of plant lines in this test; and in the Waseca test

field, it was planned to select beets from all lines which showed some resistance to the disease.

Selection of 53 lines was made from the Mason City test in late September, after a recheck of vigor and stand notes had been made. In table 2 are given vigor indices and stand counts obtained on these selections, compared with check varieties.

Table 2. Average percentage stand and vigor indices for 53 selected plant lines compared with the average of all lines tested, and with susceptible checks, Mason City, Iowa, 1947.

Varieties	Vigor of Foliage Indices*		Percent Stand	
	Average	Range	Average	Range
195 lines in test.....	2.96	1.0-5.0	56.75	22.5-87.5
53 lines selected.....	2.45	1.0-3.0	69.34	55.0-87.5
Check varieties :				
U.S. 216.....	4.12		52.00	
1-9-00.....	4.74		25.48	
American 3.....	4.29		38.40	

*Vigor Index: 1 = vigorous, 5 = weak.

From the 53 lines selected in this field, a total of 557 beets were obtained, all of which weighed more than 0.7 pound per beet.

The striking difference in stand and vigor of foliage between resistant lines and checks in the Mason City test is shown in figure 1. The susceptibility of the check varieties to root rot is observable in both the first and second rows of 20-foot plots, as compared to the several resistant lines growing in adjacent rows.



Figure 1. —(Foreground) left to right: American No. 3, 1-9-00, U.S. 216, A-122, A-132, A-102.

Figure 2 shows selected roots of resistant line A-93, compared with the roots of the American No. 3 check. A-93 produced 30 beets from 40 feet of row (2 plots), 13 of which were selected. The check variety produced 12 beets from 40 feet of row, 11 of which are shown.

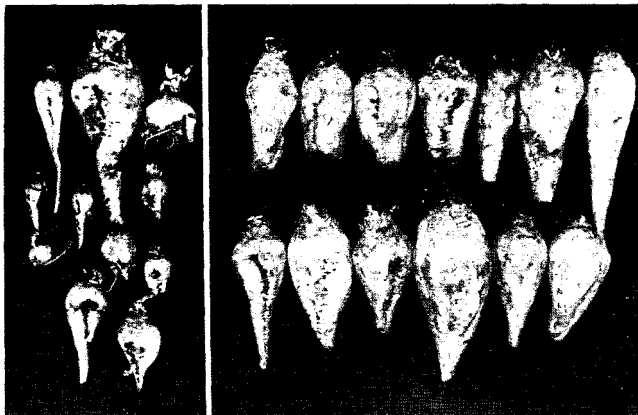


Figure 2.—Left, American No. 3 check; right, line A-93.

In December 1947, a further separation of the roots of the 53 lines was made for size and shape, into (a), (b), and (c) selections. This procedure was considered desirable, since not all roots selected can be accommodated in the greenhouses; and further, since the less desirable plants of this final selection were far superior in resistance to the check varieties in the test field, these are usable for commercial bulk-seed increase as a semi-resistant variety. The (c) selection was of beets weighing more than .70 pound and less than 1.40 pounds. Beets of the (a) and (b) selections weighed more than 1.40 pounds per beet; and the (a) selection was of lines having the largest number of beets weighing more than 1.40 pounds. Data on these final selections is given in table 3.

The replicated test plantings at Waseca, Minnesota, and the nursery plantings of self and sib progenies at Rocky Ford, Colorado, were also used for selection purposes. Of the 195 progeny lines in the Waseca test, 46 were considered resistant enough to be selected, and 205 beets were obtained. At Rocky Ford, beets from 24 inbred lines and 33 sib progenies were selected. These self and sib progenies will be further inbred in the 1947-48 winter season.

Table 3.--Number of beets selected and average weight of final 1947 root rot resistant selections, Rocky Ford, Colorado, 1947.

Selection	1947 plant line	Number of beets selected	Average weight per beet, pounds
A	A-32	8	2.05
	A-66	10	1.88
	A-71	9	2.10
	A-78	8	1.75
	A-86	11	1.86
	A-93*	11	1.96
	A-106	8	1.73
	A-145	11	1.76
	A-150	9	1.91
	A-165	8	1.75
	A-184	8	1.73
	A-189	10	1.95
Total and average		111	1.87
B		170	1.87
C		276	1.03

*See figure 2.

Conclusions

The 195 individual plant lines, obtained from 20 lines resistant to *Aphanomyces cochlioides* in 1946 at Waseca, Minnesota, showed similar resistance to the parent lines in a similar epidemic at Mason City, Iowa, in 1947. Under the very severe disease conditions existing at Waseca, Minnesota, in 1947, 13 of these 195 progenies were much superior to the check varieties in resistance. These same 13 lines were superior to others in the lesser disease conditions prevalent in the Mason City test. It is concluded, therefore, that substantial resistance to this root disease has been obtained. This conclusion is further substantiated by a yield test of a seedlot representing the best of the 20 lines selected in 1946, compared with the 3 check varieties. This selection, 6-404a, produced a yield of beets five times that of the average of the three check varieties.

The 1947 test near Mason City, Iowa, showed great differences as an average, between selected lines and check varieties, but much lesser differences between lines. In the 1946 tests, the parent lines showed great differences *between lines*, as well as between all selected lines and checks. It is concluded, therefore, that future improvement in resistance in the plant material now on hand will not be as great from mass selection, or from open-pollinated mother-line selection, as from lines developed by closer breeding methods.

Summary

Seed obtained from the selection made for resistance to *Aphanomyces cochlioides* in 1946, was compared with three susceptible varieties in plot tests in a medium severely infested field in 1947. The three susceptible varieties yielded an average of 1.60 tons per acre, and the resistant selection 8.00 tons per acre.

Fifty-three open-pollinated plant lines were found to be superior in resistance out of 195 tested in 1947, in a field having a medium-severe

infestation of *Aphanomyces cochlioides*. Forty-six plant lines showed good resistance in a severely infested field. Of the 46, the 13 best lines were found to be highly resistant in the medium severely infested field.

Selections were also made in 24 inbred lines and 33 sib progenies from nursery plots, for further self-pollination and test for resistance to disease.

Literature Cited

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