A Summary of Results in the Breeding for Resistance to Aphanomyces Cochlioides (Drecks) by the American Crystal Sugar Company Since 1942

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Root rot of sugar beets caused by *Aphanomyces cochlioides* (Drecks) has been prevalent in the Minnesota and Iowa sugar beet growing areas of the United States for many years (4) -. Laggard plant growth, caused by the persistant attack of the pathogen on the seedling and the small feeder roots, and also the rot of the main root which may result in the death of the plant, are the chief manifestations of the disease. The work of various investigators of this root rot disease was summarized by Coons et al (3) in 1946.

Observations that varieties and selections of sugar beets differed in their resistance to rotting by *Aphanomyces cochlioides* led to the development of a program some 12 years ago of breeding for resistance to this organism by both the American Crystal Sugar Company and the United States Department of Agriculture. Reports on progress for resistance to this root rot have been made by a number of workers, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 and 11. Bockstahler et al (2) studied different crosses using resistant and susceptible parents and concluded that resistance to *Aphanomyces cochlioides* was Mendelian and dominant; and similar results were obtained by the research personnel of the American Crystal Sugar Company.

Procedure and Results

The selection of beets which were resistant to *Aphanomyces cochlioides* was started by the American Crystal Sugar Company in 1942 and was continued up to the present date. Very slow progress was made in the first years but recent selections have been extremely promising. Mass selection with modifications has been the main method of breeding.

A sixteen-strain test in three replications of plots were grown on soil naturally infested with *Aphanomyces cochlioides* at Mason City, Iowa, during the years 1952 and 1953. Eleven of the strains tested in 1952 also were tested in 1953. The results of these two tests are presented in Tables 1 and 2.

When comparisons were made of the yields of the varieties common in both years tested, it appears that the epiphytotic of the disease and/or the pathenogenicity of the organism was not as servere in 1953 as in 1952. However, strain 5-419, the first root rot-resistant selection produced by the Company, gave approximately the same yield in both years. Strain 1-602, selected in 1950, ranked the highest in 1952 both in tonnage yield and in pounds sugar per acre; and was excelled in 1953 only by the 1951 selection 2-703.

Strain 2-703 was a seed increase from 23 roots selected at Waseca, Minnesota, from breeding material tested under severe root rot conditions. The third ranking strain was obtained from root rot-resistant plants grown

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[2] Numbers in parentheses refer to literature cited.

lor seed production in the greenhouses at Rocky Ford, Colorado, during the winter of 1952-53. The seed from outstanding plants was bulked together and labeled as RF GH No. 5.

Five new selections were added to the 1953 strain test. All of the selections, except the commercial American No. 3 S which was included as a second check, were breeders' stocks selected under root rot conditions. The new selections ranked high in yield with the lowest (0-804) holding seventh position.

Table I.—.Mason City Root Hot Strain Test—1952.

Variety	Year of Selection	Tons Beets per Acre	Percent Sucrose	Lbs. Sugai per Acre	% Na	% K
1^602	1950	loTsS	14.05	" 2,985 ~	J029	Tl48
I-604[1]	1950	9.68	14.33	2.773	.041	.149
1-607	1950	9.26	14.38	2,648	.032	.151
7-609-X	1946	9.40	14.05	2,634	.040	.137
1-703	1950	9.03	14.45	2.605	.027	.124
1-4060	1949	9.07	13.72	2.495	.033	.154
0-602	1949	8.22	14.57	2,402	.034	.140
1-4062	1950	7.99	14.45	2,305	.038	.148
9-406-0	1947	9.46	14.33	2,249	.033	.146
1-802	1950	7.71	14.23	2,188	.031	.147
9-801	1950	6.68	13.42	1,790	.041	.166
Am No. 3 LSR	check	5.80	14.72	1,706	.033	.146
1-4061	1949	6.34	12.98	1,645	.052	.157
6-423-X	1945	5.88	13.48	1,572	.036	.151
1-4007[2]	1949	5.20	14.18	1,472	.031	.161
5-419	1944	5-31	13.83	1,452	.039	.143
General Mean		7.85	14.07	2,183	.036	.148
Sig. Diff. (19:1)		2.42	.84	732	.011	NS[3]

[1] A selection of U.S.D.A.—48-B3-00.
[2] Selected for rhizoctonia resistance.
[3] Not significant.

Table 2.—Mason City Root Rot Strain Test—

Variety	Year of Selection	Tons Beets per Acre	Percent Sucrose	Lbs. Sugar per Acre	Na	% Ca	% Raff
2-703	1951	K5.66	16.93	5,299	J)35	.007	TTe
1-602	1950	14.55	17.78	5,141	.023	.007	.167
RF GH No. 5	1951	13.50	17.42	4,703	.030	.007	.148
5O-B3-0*		12.53	17.33	4,345	.038	.007	.175
1-607	1950	12.15	17.65	4,272	.022	.008	.200
1-703	1950	12.46	17.07	4,250	.045	.007	.165
0-804[2]	1949	12.28	17.25	4,229	.033	.006	.135
1-604[3]	1950	11.07	18.18	3,983	.032	.006	.192
9-406-0	1948	11.11	17.41	3,872	.026	.008	.125
Am No. 3 S	check	11.26	17.17	3,854	.034	.006	.150
0-603	1949	9.54	17.87	3,399	.028	.006	.142
Am No. 3 LSR	check	9.30	17.62	3,293	.026	.006	.125
1-802	1952	9.47	17.15	3,255	.030	.006	.120
9-801*	1948	8.33	17.73	2,962	.037	.006	.140
6-423-X	1945	7.58	16.97	2,557	.034	.007	.175
5-419	1944	4.79	17.03	1,656	.042	.008	.192
General Mean		10.97	17.41	3,817	.032	.007	.154
Sig. Diff. (19:1)		3.33	NSs	1,113	NS	NS	NS

[1] U. S. No. 400.
[2] First selection, Amer. No. 3N.
[3] Selection from U.S.D.A. 48-B3-00.
[4] First selection, Amer. 3LSR.
[5] N.S. = non significant.

Two selections of U.S.D.A. root rot-resistant varieties were entered in the 1953 test. Strain 1-604 was a reselection of the U.S.D.A. number 48-B3-00; and 50-B3-0 was recently released by the United States Department of Agriculture as U. S. 400. Selection 1-604 also was tested in 1952 and ranked second in yield of total pounds of sugar produced per acre. In the 1953 test, the two selections 1-604 and 50-B3-0 ranked eighth and fourth respectively, for sugar per acre yield.

It is evident from the data given in Tables 1 and 2, as well as from Figure 1, that in the past 10 years there has been a great advance in the breeding for resistance to *Aphanomyces cochlioides*. It is obvious that the recent selections are superior to the present commercial check varieties, as well as the earlier selections.

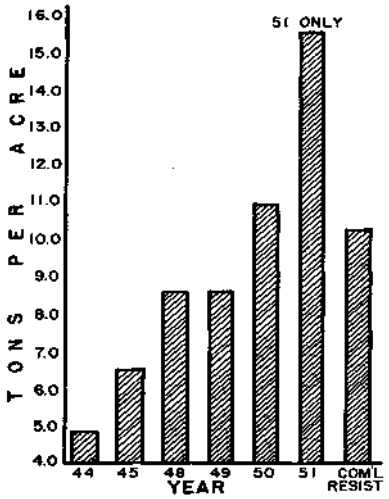

Figure 1.—The resistance obtained to Aphanomyces root rot, 1944-1952. A two year average (except the 1951 —one year average) of seven Aphanomyces root rot resistance strains and the increased resistance obtained during the past eleven years of breeding for resistance to Aphanomyces root rot.

The criterion used for determining resistance to Aphanomyces root rot has been pounds sugar produced per acre. This standard contains two important components; percent sucrose and tons of beets per acre. The tonnage component also contains two factors, yield genes and root rot-resistant genes. As of this date it has not been possible to separate the two. The correlations in Table 3 are of interest, but they offer no method for separating the above two factors.

Highly significant correlations were obtained between tons of beets per acre and pounds of sugar per acre in both years. This would be ex pected, as tonnage is the most important component in the amount of sugar produced per acre.

Table 3.—Correlation Coefficients of Seven Characteristics of Sixteen Varieties Tested Under Root Rot Conditions at Mason City, Iowa.

	Tons per Acre	Percent Sucrose	Lbs. Sucrose per Acre	% Na	% Ca
		1952			
Percent Sucrose	.325				
Lbs. Sugar per Acre	.970[2]	.414			
% Na	—.288	—.644[2]	—.388		
% K	—.377	—.526[1]	—.426	.374	
		1953			
Percent Sucrose	.062				
Lbs. Sugar per Acre	.997[2]	.137			
% Na	—.257	—.522[1]	—.300		
% Ca	.022	—.293	.085	.013	
% Raffinose	.191	—.202	.170	—.146	—.437

[1] 5% r = .497.
[2] 1% r = .623

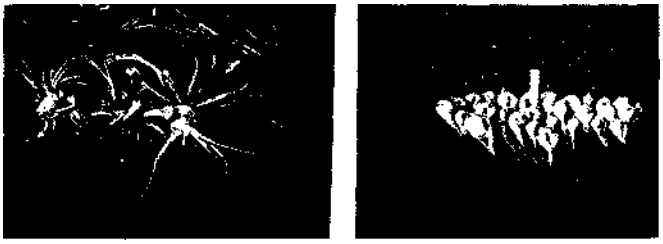

Figure 2.—Differences between two inbred lines which appeared resistant to root rot when looking at top growth.

Significant negative correlations were obtained between sodium and sucrose in 1952 and 1953, and in 1952 between sucrose and potassium, which is in agreement with the findings reported by Doxtator and Bauserman (9) .

Along with the mass selection breeding program for root rot resistance many outstanding plants have been selfpollinated. The objective of inbreeding is twofold: A. to isolate desirable biotypes, and B. to change the gene frequency, since differences in inbred lines are due to the changes in gene frequency. One of the extremely promising inbred lines is shown in Figure 2, compared to a completely unsatisfactory selfed line. With the objective to obtain hybrids, increased emphasis is now being placed on inbreeding and the isolating of desirable biotypes.

Summary

Remarkable advances have been made since 1944 by the American Crystal Sugar Company as well as by the United States Department of Agriculture in obtaining beets resistant to the root rot caused by *Aphanomyces cochlioides.*

New selections are definitely more resistant than the first selected strains. Inbred lines which are highly resistant to *Aphanomyces cochlioides* are now being studied.

ACKNOWLEDGMENT

The improvement in root rot resistance obtained since 1952 could not have been achieved had it not been lor the whole hearted cooperation of company research assistants, factory managers, agriculturists and many others.

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