Progress Report on Breeding of Sugar Beets in Minnesota for Resistance to Black Root[1]

H. W. Bockstahler and Oscar E. Reece[2]

In recent years the disease of sugar beets, commonly called black root, has received increased attention from numerous investigators. *Aphanomyces cochlioides* drechs. has been found most frequently in the humid area of the United States, although many fungi may be involved in this disease complex. This fungus parasite is capable of killing both seedlings and older sugar beet plants. A review of the black-root disease problem and possibilities for its control was presented at the fourth general meeting of this Society in 1946 (1).[3]

Observations that varieties of sugar beets differ in their resistance to rotting by *A. cochlioides* led to the development of a program of breeding for resistance to this organism by the Division of Sugar Plant Investigations, United States Department of Agriculture, and Minnesota Agricultural Experiment Station. A preliminary report on this project was presented by Henderson and Bockstahler (3) in 1946. A similar project was undertaken by the American Crystal Sugar Company as reported in 1947 by Doxtator and Downie (2). Active cooperation between these agencies was begun in 1946 and continued in 1947 for the field testing of resistant selections. This paper is a progress report presenting the results of field tests in 1947 of selections developed by the Division.

Materials and Methods

Seed Sources.—The seedlots tested in 1947 were individual plant progenies derived from open-pollinated mother beets in the greenhouse and in the field. The seed obtained in the greenhouse was produced by the polycross method whereas that from the field was produced in a group planting of beets from several different varieties or group plantings of beets from single varieties.

For the polycross method of seed production roots having acceptable size and shape were selected in a field heavily infested with *A. cochlioides* in the fall of 1945 and placed in cold storage until December 1. The best 15 roots from 50 lines were then planted in 8-inch pots and placed in the greenhouse arranged in 15 blocks of 50 roots each.

[1]Cooperative investigations of the Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U.S. Department of Agriculture, and Minnesota Agricultural Experiment Station, Paper No. 2396. Scientific Journal Series, Minnesota Agricultural Experiment Station.

[2]Assistant Pathologist, and Assistant Agronomist, respectively, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering. The writers wish to thank Dr. G. H. Coons, Principal Pathologist, Division of Sugar Plant Investigations, Bureau of Plant Industry, Soils, and Agricultural Engineering, U.S. Department of Agriculture, under whose direction these investigations were made, and Dr. H. K. Hayes, Chief, Division of Agronomy and Plant Genetics, and Dr. E. C. Stakman, Chief, Division of Plant Pathology and Agricultural Botany, Minnesota Agricultural Experiment Station, for helpful suggestions and criticisms during the course of these investigations and in the preparation of the manuscript.

[3]The numbers in parentheses refer to literature cited.

Each block contained 1 root from each of the 50 lines randomized within the blocks to permit equal opportunity for cross-fertilization to occur between the different lines. At intervals during the period of flowering a hand electric blower was directed toward the plants to aid in the dispersal of pollen. Of the 750 roots planted, 569 came into flower and were harvested individually.

The surplus roots not used in the greenhouse were retained in storage until May, 1946. All sound roots were then planted in the field at Waseca, Minnesota, in three isolated groups spaced approximately ¼-mile apart: 1.—mother beets from selections of U. S. 216; 2.—selections from Minnesota Synthetic No. 1 and 3.—all remaining beets from various sources including extra roots from some of the lines used in the polycross. By planting these mother beets at Waseca where the soil was heavily infested with *A. cochlioides* it was hoped that additional elimination by disease might occur. At harvest, seed was saved from only those plants whose roots were still solid and showed no signs of rot.

Field Plot Methods

The tests were made in heavily infested soil at the Southeastern Experiment Station, Waseca, Minnesota. In cooperation with the American Crystal Sugar Company, four additional tracts were located in Southern Minnesota, however, in two of these, disease incidence was moderate and no disease was evident in the others so that only the plots at Waseca were harvested.

Rows, 20 inches apart, were marked with a 4-row beet drill and fertilizer (4-24-12) applied in the row at the rate of 100 pounds per acre. All seed was treated with Arasan and planted with a V-belt hand planter of the type commonly used for planting small grains at the Minnesota Agricultural Experiment Station. Plots were single rows 10 or 20 feet long, depending on the quantity of seed available. All seedlots were planted in duplicate, randomized plots with the exception of a few in which only sufficient seed was available for a single 10-foot row. As check varieties, U. S. 216, moderately resistant; S.P. 1-9-00, very susceptible, and American No. 3, moderately resistant commercial variety, were planted at 12-row intervals throughout the field.

Stand counts after thinning and relative vigor of top growth in comparison with U. S. 216 were recorded. These data were used to determine the progenies considered worth lifting at harvest. In order to verify these conclusions, 310 twenty-foot rows were lifted and the roots sorted into healthy and diseased classes. Size and shape of roots were used as the basis for the separation. When compared with the roots of U. S. 216 from the nearest plot of that variety, the above conclusions were justified and harvest of the remaining progeny rows was determined on that basis.

The performance of each progeny row was compared with that of the nearest row of U. S. 216 and classified into six categories as follows:

Class +3, three times as many healthy roots as U. S. 216; +2, two times; +1, one and one-half times; 0, equal; -1, less; and -2, not harvested but inferior to U. S. 216 in stand and top growth vigor. This paper presents the results of the field tests of 506 open-pollinated seed progenies from mother beets planted in the greenhouse and 127 open-pollinated seed progenies from mother beets planted in the field.

Experimental Results

The development of sugar beet varieties resistant to *A. cochlioides* consists essentially in exposing mixed populations to the soil inhabiting pathogen. Genetic changes in both the host and the pathogen may operate to complicate the problem. Through successive exposures susceptible plants may be screened out leaving the resistant individuals. When seasons unfavorable to the fullest development of reaction between host and pathogen are encountered, the screening process is incomplete and must be continued in succeeding years. The tests in 1947 were the second severe exposure of the selections to disease in the field.

The results of the performance of 506 progenies from seed produced in the greenhouse by the polycross method in comparison with the check variety, U. S. 216 are given in table 1. One hundred and seventy-five progenies (34.6 percent) produced from 1½ to 3 times as many healthy roots as U. S. 216. Two hundred and forty-five progenies (48.4 percent) were equal or superior to the check.

Table 1.—Frequency distribution of mean yield of healthy roots, in heavily infested soil, of progenies of open-pollinated seed produced in the greenhouse by the polycross method in comparison with U.S. 216. (Classified according to numbers of healthy roots produced.)

Source of selection	Classes[1]						Total progenies tested	As percentages of U.S. 216		
	+3	+2	+1	0	-1	-2		Superior	Equal	Inferior
								(percent)	(percent)	(percent)
0-2-07					2	7	9			100.0
0-2-022			1		1	7	9	11.1		88.9
0-4-01	1			2		1	4	25.0	50.0	25.0
0-6-07					2	5	7			100.0
1-8-00	1	5	6	7	4	15	38	31.6	18.4	50.0
1-12-00	1			3		4	8	12.5	37.5	50.0
2-1-00			2	1	1	6	10	20.0	10.0	70.0
3-6-00	4		4	2	1	4	15	53.4	13.3	33.3
3-9-0		1	1	1		4	7	28.6	14.3	57.1
3-10-0	1	2	2			4	9	55.6		44.4
4-7-00						8	8			100.0
4-1901-01		1	3			4	8	50.0		50.0
W[2]	5	3	9	3	2	10	32	53.1	9.4	37.5
S[2]	10	23	38	29	17	67	184	38.6	15.8	45.6
W & S[2]	4	4	6	8	2	14	38	36.8	21.1	42.1
Am. No. 1		4	7	3	5	17	36	30.6	8.3	61.1
Am. No. 3		4			1	5	10	40.0		60.0
U.S. 216		1	2	1	1	7	12	25.0	8.3	66.7
Minn. Syn. No. 1	2	4	7	8	1	29	51	25.5	15.7	58.8
Miscellaneous[3]	1		5	2	3		11	54.5	18.2	27.3
Totals and averages	30	52	93	70	43	218	506	34.6	13.8	51.6

[1]Classes: +3, produced 3 times as many healthy roots as U.S. 216; +2, 2 times; +1, 1½ times; 0, equal; -1, less; -2, inferior to U.S. 216 in stand and top growth vigor so were not harvested.

[2]W, S, and W & S—selections obtained from genetic study by Dr. J. O. Culbertson. Roots above average in weight, sucrose, or both.

[3]Miscellaneous original source not recorded.

As shown in table 2, 22 (17.3 percent) of the 127 progenies from the mother beets producing open-pollinated seed in the field yielded 1½ to 3 times as many healthy roots as U. S. 216. Thirty five (27.5 percent) were equal or superior to the check. It should be mentioned that the roots which produced these seedlots were mostly residual mother beets remaining in storage after the best ones were selected for planting in the greenhouse. This may account for the poorer results from this group of progenies as contrasted with those shown in table 1. The performance of seedlots from the two plantings is compared in table 3. In each of the three sugar beet strains listed, a greater percentage of the progenies from the greenhouse or polycross planting equalled or exceeded the check than the progenies from the field plantings.

Table 2.—Frequency distribution of mean performance in heavily infested soil of progenies of open-pollinated seed produced in the field in comparison with U.S. 216. (Classified according to numbers of healthy roots produced.)

Source of selection	Classes[1]						Total progenies tested	As percentages of U.S. 216		
	+3	+2	+1	0	—1	—2		Superior	Equal	Inferior
								(percent)	(percent)	(percent)
0-1-022						1	1			100.0
0-2-07			2				2	100.0		
0-2-026						1	1			100.0
0-4-01					1	1	2			100.0
0-10-0						1	1			100.0
1-7-00		1				1	2	50.0		50.0
1-8-00		1	3	1	3	1	9	44.4	11.2	44.4
1-10-0			1				1	100.0		
1-19-0						1	1			100.0
2-1-00	2			1		11	14	14.3	7.1	78.6
3-9-0						3	3			100.0
3-10-0						2	2			100.0
3-1311-0						2	2			100.0
4-14-0			1	2			3	33.3	66.7	
4-1901-01			3	2	1	8	14	21.4	14.3	64.3
8-266-0						1	1			100.0
Lot 1233		1				1	2	50.0		50.0
Am. No. 1						2	2			100.0
Am. No. 3						1	1			100.0
U.S. 216				1	1	14	16		6.3	93.7
Minn. Syn. No. 1	2		3	4	1	23	33	15.2	12.1	72.7
Misc.[2]	1		1	2	1	9	14	14.3	14.3	71.4
Totals and averages	5	3	14	13	8	84	127	17.3	10.2	72.5

[1]Classes: +3, produced 3 times as many healthy roots as U.S. 216; +2, 2 times; +1, 1½ times; 0, equal; —1, less; —2, inferior to U.S. 216 in stand and top growth vigor so were not harvested.

[2]Miscellaneous original source not recorded.

Table 3.—Comparison of sugar beet progenies from seed produced in the greenhouse by the polycross method and seed produced in the field with yield of healthy roots when compared with the check variety, U.S. 216.

Source of selection	Mother beet location	Number of progenies tested	As percentages of U.S. 216		
			Superior	Equal	Inferior
			(percent)	(percent)	(percent)
2-1-00	Greenhouse	10	20.0	10.0	70.0
	Field	14	14.3	7.1	78.6
Minn. Syn. No. 1	Greenhouse	51	25.5	15.7	58.8
	Field	33	15.2	12.1	72.7
U. S. 216	Greenhouse	12	25.0	8.3	66.7
	Field	16	0.0	6.3	93.7

Mother beets have been selected and placed in storage from many of the progenies classified as superior in the tests in 1947. Further testing and selection is necessary but progress is being made in the development of strains resistant to black-root disease.

Summary

Black root of sugar beets is caused by a number of soil inhabiting, pathogenic fungi, principally *Aphanomyces cochlioides*, in the humid area of the United States.

Observations that varieties of sugar beets differed in their resistance and susceptibility to this organism led to the development of a program of breeding for resistance.

Seed from individual mother beets was produced in the greenhouse by the polycross method and in the field. When planted in the field in soil heavily infested with *A. cochlioides*, 34.6 percent of the progenies produced in the greenhouse yielded 1½ to 3 times as many healthy roots as the check variety, U. S. 216. Seventeen percent of the progenies from mother beets planted in the field exceeded U.S. 216 in numbers of healthy roots.

The polycross progenies from the superior material presents concrete evidence of the value of intensive selection showing that inheritance of resistance and the combination of resistant lines is a method of obtaining even higher resistance.

Literature Cited

(1) COONS, G. H., KOTILA, J. E., AND BOCKSTAHLER, H. W.
1946. Black root of sugar beets and possibilities for its control. Proc. Amer. Soc. Sug. Beet Tech. pp. 364-380.

(2) DOXTATOR, C. W. AND DOWNIE, A. R.
1947. Breeding for resistance to *Aphanomyces* root rot. Proc. Amer. Soc. Sug. Beet Tech. Regional Meeting. p. 134.

(3) HENDERSON, R. W. AND BOCKSTAHLER, H. W.
1946. Reaction of sugar beet strains to *Aphanomyces cochlioides*. Proc. Amer. Soc. Sug. Beet Tech. pp. 237-245.