Further Studies on the Inheritance of Black Root Resistance in Sugar Beets[1]

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In the humid areas of the United States and Canada, production of sugar beets is threatened by a disease commonly known as black root. The pathogen, *Aphanomyces cochlioides* Drechsler, is capable of invading all parts of the root system. Laggard plant growth, caused by persistent attack of the pathogen on the small feeder roots, and rot of the main root, which may result in the death of the plant, are the chief manifestations of the disease. Seedling stands are frequently reduced, but this phase of the disease is subject to control to a large extent by seed treatment or other means. Outbreaks of black root in fields in which the plants are past the thinning stage have not been prevented effectively by direct control measures. Strains of sugar beets capable of making vigorous growth under such black root exposure, and giving a plant population at harvest not greatly reduced from that left at thinning, have been found (2, 5)[3]. Progress reports of breeding programs give promise of the development by breeding of resistant varieties for use in areas in which black root is serious (1, 3, 4) .

Henderson and Bockstahler (6) reported results with hybrids as compared with their inbred parents which indicated dominance of the black root resistance character. However, the hybrid populations as grown by them contained an undetermined percentage of plants of the maternal line.

To study further the mode of inheritance of the black root resistance character, plantings of sugar beet hybrids and their parental lines were made in 1949 in soil naturally infested with *A. cochlioides* at Waseca, Minnesota, East Lansing and Blissfield, Michigan. Many of the parental lines had been tested previously and the disease reaction of these was known. In most of the hybrid populations the F_1 plants could be identified in the seedling stage by hypocotyl color or in the larger plants by bud color. The performance of two hybrids and their parental lines is selected for tabulation as giving the most decisive results. The results of the tests as a whole are given as general statements of performance.

Materials and Methods

Single-row plots 20 feet long were used in all tests. The parental lines and hybrid were planted in adjacent plots. Two of these parent-hybrid-parent groups were planted at each of the three locations. A susceptible variety was planted at regular intervals to serve as an indicator of the uniformity of disease exposure.

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[3] Numbers in parentheses refer to literature cited.

All seed lots were treated with Arasan to reduce seedling losses. Estimates of seedling stands were taken before thinning. Spacing of approximately 12 inches in the row was used. In hybridizations involving inbreds of unlike bud color, the seedling populations were thinned to give a complete stand of F_1 plants so far as possible. In some plots of hybrids it was necessary to leave plants unidentified as to hybridity if a uniform spacing was to be maintained. Harvest data included number of roots and weight of roots for each plot.

Experimental Results

Line A, used as the pollen parent in hybrids J x A and B x A of Table 1, in homozygous dominant for the factors determining pink bud color, and the maternal Lines B and J are of the recessive genotype. Thus, *in* these two crosses all F_1 plants can be identified in the progeny of B or J. From previous tests Lines A and J had been classed as black root susceptible, and Line B resistant. Their performances in these tests were *in* agreement with the previous classification. It should be mentioned that the hybrids used in these tests were known to give satisfactory yields in absence of black root. The inbreds A and J had been considered valuable as breeding material before their reaction to black root was observed.

Hybrid J x A produced by the mating of two susceptible lines gave performances as to mean root yield and stand at harvest not strikingly unlike that of the susceptible check SP 1-9-00. When the susceptible Line A was mated with resistant Line B, the hybrid gave a performance strikingly unlike that of J x A. The hybrid B x A gave a higher mean root weight than either parent and a gain of 46% over that of the susceptible check. The plants in 100 feet of row at harvest showed a higher survival in the hybrid over that of the susceptible lines and their hybrid. The difference in performance of the hybrids J x A and B x A in which the susceptible Line A occurs as the pollen parent is attributed to the resistant character in Line B. In these hybrids, the black root resistance in Line B is transmitted to the hvhrid as a dominant character.

For the entire planting of many hybrids and parental lines at the three locations, a covariance analysis of the data for emergence stands and final stands failed to show that the emergence stand had any effect upon the final stand. This indicates that factors other than seedling diseases operated to reduce the stand between emergence and harvest.

When the strains in this experiment were grouped according to type of reaction, the mean plot yields of the four classes were as follows: (1) Susceptible parents 9.61 pounds; (2) susceptible x susceptible hybrids 9.60 pounds; (3) resistant x susceptible hybrids 14.13 pounds; and (4) resistant parents 13.76 pounds. Upon applying the "t"-test, it was found that the probability that the resistant x susceptible hybrid will yield the same as the resistant parent exceeds the 50 percent point. The probability that the resistant x susceptible hybrid will yield as low as the susceptible parent is less than 1 percent. This test also showed that the probabilities that the susceptible and resistant parents would yield the same are less than 2 percent. In the susceptible classes the average yields of the parents and the hybrids were so nearly identical no "t"-test was required.

Discussion

From the results of this experiment it appears that in a resistant x susceptible cross the reaction of the resistant parents is transferred to the hybrid since the yield of the hybrid equals or is better than that of the resistant parent and, in nearly all cases, is significantly better than that of the susceptible parent. Similar trends were observed in the tests in 1945 in Minnesota (6) . Any hybrid vigor that might be expected when susceptible inbreds were crossed apparently was nullified by the disease effects. Variability between plots with respect to incidence of black root proved a disturbing factor in the tests. Large plant populations, together with more replicates at each location, are needed to increase precision. Increase of plot length and selection of test areas with more uniform infestation with the pathogen may be effective in this regard. The resistance of many of the parent strains included in the experiment traces to variety US 216, which is only moderately resistant to black root. As inbreds are produced which show greater resistance to the disease, or vice versa, inbreds with greater susceptibility, we may expect more outstanding contrasts between the various classes of hybrids, and the effect of the dominant factors for resistance will be more pronounced.

Table 1.—Comparisons of sugar beet hybrids with their respective parental lines in tests at Waseca, Minnesota, Blissfield and East Lansing, Michigan, under black root exposure.

Current S.P. Numbers	Description	Mean Root Weight[1] Pounds	as % Check	Stand-[2]
1-9-00	Susceptible Check	0.7,000	100.0	61
451043-0	Line J (susceptible)	0.5,652	80.7	66
451805-02	J x A (susc. x susc.)[3]	0.7,500	107.1	74
461001-0	Line A (susceptible)	0.7,634	109.1	71
46116-01 (MS)	Line B (resistant)	0.9,036	129.1	83
471807-02	B x A (res. x susc.)[3]	1.0,218	146.0	87
461001-0	Line A (susceptible)	0.6,627	94.7	67

[1] Calculated from total weight of all roots at harvest in 5 single-row plots 20 feet long.
[2] Total plants harvested from 5 single-row plots 20 feet long.
[3] Identified F_2 plants in Hybrid J x A and Hybrid B x A were 87.5 and 97.5 per cent, respectively. In these crosses the F_2 plants can be identified by bud color since Lines B and J are of genotype rr and Line A is homozygous for the dominant allele.

Summary

Inbred strains of sugar beets, classified as either susceptible or resistant to black root, and hybrids between them were planted in naturally infested soil in Michigan and Minnesota in 1949.

In average root yield per plot susceptible x susceptible hybrids were not significantly different from their parents. Resistant x susceptible hybrids yielded as much as, and usually more than, the resistant parents and significantly more than the susceptible parents.

The hybridization of a resistant line and a susceptible one gave a hybrid with the disease reaction of the resistant parents. The hybridization of susceptible lines gave a susceptible hybrid.

The conclusions reached in previous work that resistance to black root is transmitted to the hybrid as a dominant is confirmed *in* these tests.

Analysis of variance for average root yield per plot failed to show significance for the differences between the susceptible x susceptible hybrids and their parents. On the other hand, comparisons between hybrids and parents of the resistant x susceptible cross showed that all hybrids outyiclded their susceptible parent, although in some cases the differences approached but did not reach significance.

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