Transferring Cercospora Leaf Spot Resistance From Beta Maritima to Sugarbeet by Backcrossing[1]

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Introduction

Leaf spot, caused by *Cercospora beticola* Sacc. (1)[3], is one of the most widespread diseases of sugarbeet and thus is a serious problem in sugarbeet production throughout the world. The disease damages the leaves and consequently reduces yield of roots, percentage sucrose, and purity (4).

Control of leaf spot can be effected by dusting or spraying with commercial fungicides, but the development of resistant varieties or strains of sugarbeet now offers a more practical solution to the problem. A number of varieties with moderate levels of leaf spot resistance have been introduced by the U.S. Department of Agriculture and U.S. beet sugar companies in an attempt to meet the requirements in various districts (2). Such varieties have given only partial control of the disease, and the production of varieties with higher levels of resistance is needed.

The wild beet, *Beta maritima* L., seems to be an excellent source of high resistance to leaf spot. This study was conducted to appraise *B. maritima* as a source of leaf spot resistance and to evaluate the backcross method of plant breeding as a tool for transferring the high resistance of *B. maritima* to sugarbeet.

Materials and Methods

The crosses, selections, and reproductions involved in this breeding study were made under the direction of J. O. Gaskill at the U.S. Sugarbeet Research Station in Fort Collins, Colorado. The first cross, US 22/4 [multigerm (MM), curly top resistant (CTR), leaf spot susceptible (LSS)] $\times$ *B. maritima* [MM, leaf spot resistant (LSR)], was made in 1956. F_1 hybrid seed from this cross was planted the following year. Eighteen hybrid plants were chosen after selection for leaf spot resistance, root size and shape. These 18 selected plants were backcrossed to SL 539

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[3] Numbers in parentheses refer to literature cited.

[monogerm (mm), CTR]. From the first backcross generation, eight beets were selected for leaf spot resistance, root size, and shape. These beets were planted in the field and allowed to interpollinate. The resultant seed (B_1OP_1) was planted in the greenhouse; the young seedlings were photothermally induced (3); and 33 plants were selected for the monogerm character from the segregating generation. No selection was made in this generation for leaf spot resistance. The 33 selected plants were allowed to interpollinate, and the resultant seed was planted in the field the following year. After selection for leaf spot resistance, root size and shape, 14 roots were chosen. These again were backcrossed to a leaf spot susceptible variety, McF. 663 (MM. CTR). The resultant second-backcross seed was planted the following year and selections were made for leaf spot resistance, root size and shape. Thirty-five selected beets were planted in 1965 for the production of an open-pollinated generation (B_2OP_1). No selection was made for sucrose after either the original cross or the backcrosses.

Four populations were planted in the field in 1966 in a randomized complete block design with 22 replications:

1. A leaf spot susceptible sugarbeet variety—an increase of McF. 663.
2. *B. maritima.*
3. B_1OP_1—first open-pollinated generation following the B_1.
4. B_2OP_1—first open-pollinated generation following the B_2.

Single-row plots, 20 feet long, with 20 inches between rows, were alternated with rows of a susceptible sugarbeet line. Plants in the entire field were inoculated by means of a spore suspension prepared from diseased sugarbeet leaves collected in the preceding year. Supplemental sprinkling of the field, in addition to normal furrow irrigation, was used as an aid in developing an epidemic of leaf spot. Leaf spot readings were made on 16 individual plants in each plot at the peak of leaf spot development. Individual plant weight records and sucrose analyses also were made after harvest in all populations except in *B. maritima.* Ten plants were taken from each plot for this purpose. A composite sample of plants was taken from each plot of *B. maritima* for weight and sucrose analyses because of the small branched roots in this population. The scale used for leaf spot readings was "O" for no leaf spot and "10" for completely defoliated plants, a scale commonly employed by Sugarbeet Investigations, Crops Research Division, Agricultural Research Service, U.S. Department of Agriculture.

Results and Discussion

Some bolters (i.e., plants with seedstalks) occurred in populations having *B. maritima* parentage. To decide whether or not to use the leaf spot readings of bolters, *t* tests were applied to the means of readings of bolters and non-bolters. The means and their standard errors are given in Table 1. The differences between the leaf spot reading means of the bolters and non-bolters were significant at the 1% level. Consequently, all bolting plants were excluded in subsequent analyses of the data. Of the plants to which leaf spot readings were given in each plot, the first 10 non-bolters were used for these analyses.

Population means and standard errors for leaf spot readings, weight per root and percentage sucrose are given in Table 2. The open-pollinated backcross populations had acceptable weights and sucrose percentages, and their leaf spot readings were substantially lower than the readings for the sugarbeet variety (population no. 1).

Some fluctuations may be observed in total within-plot variances given in Table 3. These variances were obtained by calculating the variance within single plots and dividing the sum of the single-plot variances by 22 for a given population. This

Table 1.—Leaf spot reading means and standard errors for bolters and non-bolters.

Pop. No.	Non-bolters	Bolters
1	6.07±0.13	------
2	2.35±0.12	4.75±0.42
3	4.93±0.10	7.05±0.23
4	4.83±0.14	5.75±0.48

Table 2.—Population means and standard errors for leaf spot, weight per root, and percentage sucrose.

Pop. No.	Leaf spot reading	Weight per root	Sucrose
		(kg)	%
1	5.990±0.07	0.183±0.01	14.105±0.09
2	2.415±0.06	0.060±0.02	10.920±0.17
3	4.936±0.07	0.395±0.01	14.869±0.09
4	4.850±0.07	0.492±0.01	15.039±0.07

Table 3.—Total within-plot variances for leaf spot readings, weight per root, and percentage sucrose.

Pop. No.	Leaf spot readings	Weight per root	Percentage sucrose
1	0.7464	0.0349	1.3185
2	0.8614	-------	-------
3	0.8828	0.0290	1.4940
4	0.8479	0.0416	1.0985

method excludes the variation due to replications and that due to the interaction of population × replications. It gives one an opportunity to look at random and genetic variability within the plots.

Population 1 had the lowest total within-plot variance for leaf spot and provided the best available estimate of the environmental variance for leaf spot. This population is assumed to be fairly homozygous for leaf spot susceptibility. However, some genetic variance must remain in this population. Therefore, heritability ratios based on this assumption are conservative broad-sense estimates or minimum estimates. Calculated broad-sense heritability ratios were 0.134, 0.155, and 0.120 for populations 2, 3, and 4, respectively.

Univariate frequency distributions for leaf spot readings are presented in Figure 1. It is clear from these results that the open-pollinated backcross populations had valuable individuals for leaf spot resistance. For example, there were five plants with a leaf spot reading of 2 in the B_2OP_1. This is a relatively high

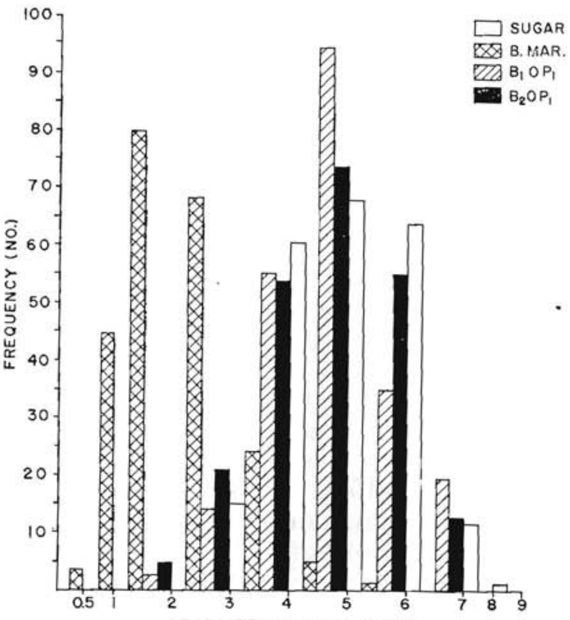

Figure 1.—Univariate frequency distributions for leaf spot readings in all populations.

proportion of individuals in a population of 220, and it is considered very promising to have 2.3% highly resistant individuals in a leaf spot breeding program as a basis for further selection. Root weights and sucrose percentages for the five leaf spot resistant plants are given in Table 4.

Table 4.—Root weights and sucrose percentages of the five highly resistant individuals in the B_2OP_1 population.

Leaf spot reading	Root weight	Sucrose
	(kg)	(%)
2	0.90	15.0
2	0.60	15.6
2	1.05	15.6
2	0.45	15.0
2	0.75	14.8

It is apparent that the open-pollinated backcross populations included plants with valuable leaf spot resistance and acceptable root weight and percentage sucrose. Thus, the results of this study demonstrate the feasibility of transferring the leaf spot resistance of *B. maritima* to sugarbeet by backcrossing. Assuming a large population on which to base selection, it is very likely that much progress could be made in a short time toward leaf spot resistance, without appreciable sacrifice of root yield and sucrose.

Summary

This study was made as an evaluation of: (a) *Beta maritima* as a source of *Cercospora* leaf spot resistance; and (b) the backcross method of plant breeding as a tool for transferring leaf spot resistance from *B. maritima* to sugarbeet.

A comparison of the leaf spot readings on bolting vs. nonbolting plants showed that the bolting phenomenon was positively associated with leaf spot susceptibility in this experiment; thus it was concluded that leaf spot readings should not be taken on bolting plants in a leaf spot breeding program.

Genetic variation and heritability ratios for leaf spot were relatively low in open-pollinated backcross populations due to an over estimation of the environmental variance. However, it was apparent from the study of leaf spot frequency distributions that there were highly resistant individuals with acceptable weight and sucrose percentage in the backcross progenies, especially in the B_2OP_1. Selection of such individuals in a large population should make possible substantial progress toward the development of a leaf spot resistant sugarbeet variety.

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