Fusarium Stalk Blight Resistance in Sugarbeet

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INTRODUCTION

The Willamette Valley of Oregon is the principal sugarbeet seed production area of the United States. The crop is frequently damaged by a disease that causes wilting and eventual death of the seed plants. In severely affected fields over 50 percent of the plants show symptoms and seed yields are reduced. In 1973, Gross and Leach (1) identified the causal organism as *Fusarium oxysporum* Schlecht f. sp. *betae* (Stewart) Snyder and Hansen and called the disease stalk blight. In 1976, MacDonald, Leach, and McFarlane (2) reported a wide range in resistance among cultivars and parental lines that were grown in the Willamette Valley. The inbred cytoplasmic male-sterile lines 562HO and 563HO were found to be severely damaged by the disease. These lines are widely used by both the United States Department of Agriculture and commercial breeders in the production of hybrid seed for use in California and other parts of the United States. Beginning in 1976 a breeding program was started to improve the resistance of these parental lines.

MATERIALS AND METHODS

Field tests were made for 5 years (1976-80) in a *Fusarium* infested field near Salem, Oregon. Plantings were made in August or September of each year and the material was classified for *Fusarium* resistance the following August. Lines that were to be evaluated for resistance were replicated two to four times and material for selection was planted in blocks of several hundred plants. The grading system was

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similar to that developed by MacDonald, Leach, and McFarlane (2). Each entry was evaluated by examining 50 or more consecutive plants in a given plot. The plants were pulled and examined for vascular discoloration. The plants were assigned grades on a discontinuous scale--0 = no disease, 1 = slight vascular discoloration, 2 = moderate vascular discoloration, 3 = severe vascular discoloration, and 4 = complete vascular discoloration with seed stalks dead (Fig. 1). A weighted mean or disease rating was computed based on the number of plants in each grade. Plants that were graded 0 to 1 were considered resistant.

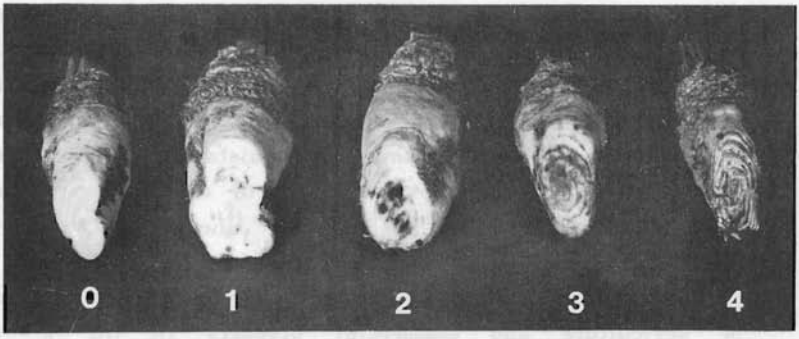

Figure 1. Standards used in classifying sugarbeet roots for resistance to Fusarium stalk blight. The roots are assigned grades on a discontinuous scale - 0 = no disease, 1 = slight vascular discoloration, 2 = moderate vascular discoloration, 3 = severe vascular discoloration, and 4 = complete vascular discoloration with seed stalks dead.

Selections for resistance were made by examining the roots of all plants in a block planting of a given line and saving seeds from plants that graded either 0 to 1. Emphasis was placed on selections within self-fertile populations that produced primarily selfed seeds. Plants from any outcrosses that occurred could be readily identified by vigor or hypocotyl

color and then eliminated. Cytoplasmic male sterile (CMS) equivalent lines were produced by crossing the selected resistant lines with closely related CMS lines and then backcrossing to the resistant line.

Information on inheritance of resistance and linkage was obtained by observing the segregation in F_2 and backcross populations from F_1 hybrids between resistant and susceptible parents. Mendelian and cytoplasmic male sterility were utilized to produce hybrids between self-fertile inbred lines.

RESULTS AND DISCUSSION

Range in resistance: Tests made in each of 5 years showed that a wide range in resistance exists among sugarbeet breeding lines. Disease ratings for a representative group of inbreds (Table 1) included in a replicated 1979-80 test ranged from 0.01 to 3.97. The differences among inbreds were highly significant but variations among replications were also high. Disease ratings for the 564aa inbred ranged from 2.60 to 3.94 among four replications. These results indicated that *Fusarium* infestation occurred throughout the test field but that the level of infestation was variable. During the 5 year period, the

Table 1. *Fusarium* stalk blight resistance of sugarbeet inbreds replicated four times in a test at Salem, Oregon, 1979-80.

Inbred	Description	Ave.1/ Grade	%2/ Resistant
554-14	S_{14} of 554 inbred	0.01	100
554	Bolting res. inbred	0.17	98
566	Fus. res. sel. 563	0.30	95
566HO	564 CMS x 566	1.63	59
563HO	CMS of 563 inbred	2.49	32
564aa	Mendelian male sterile 564	3.47	11
564HO	CMS of 564	3.95	0
564	Bolting res. inbred	3.97	0
LSD (.05)		0.48	

1/ Rated on scale of 0 to 4 with 0 = no disease and 4 = dead plant. Grade is average for number of plants observed.

2/ Plants in grades 0 to 1 are considered to be resistant.

tests were all made in the same 10 acre-field but were moved from one area to another within the field. Each of the areas was infested with *Fusarium* but the level of infestion varied from one area to another (Table 2).

Table 2. Variation in *Fusarium* stalk blight grades of sugarbeet breeding lines for the years 1976-80.

Breeding Line	1976	1977	1978	1979	1980
			Grade1/		
554	--	0.09	0.08	0.08	0.17
554-14	0.04	--	0.10	0.09	0.01
564	3.86	3.60	3.62	--	3.97
564HO	--	4.00	3.09	--	3.95
502HO	0.39	0.40	0.47	--	1.73
563	2.48	2.90	1.35	--	--
563HO	--	2.20	1.00	--	2.49
522	2.98	1.00	0.35	--	1.81
536-97	3.27	2.90	1.30	--	3.23
566	--	--	0.20	0.25	0.30
C13	--	0.70	0.07	0.27	1.35
564H1	1.42	1.20	0.09	0.67	3.03
522H21	2.07	1.00	0.45	1.73	3.22

1/ Rated on scale of 0 to 4 with 0 = no disease and 4 = dead plant. Grade is average for number of plants observed.

Selection for resistance: The objective of the selection program was to develop a stalk-blight resistant monogerm inbred line and its CMS equivalent that were similar in performance to the parental lines 562 and 563. Two methods were used to meet this objective: (1) Crosses were made between the Mendelian male sterile segregates of 563 and a closely related multigerm inbred with moderate resistance to stalk blight. Selections were then made in the F_2 generation. (2) Differences in resistance were observed among plants within 563 and other partially inbred lines. Selections were made directly from these inbreds.

The increase of the best segregate in a F_2 population from a cross between 563aa and multigerm inbred 502 had

a disease rating of 0.76 (Table 3). Selection 566 made directly from the 563 inbred graded 0.30 compared with the grade of 1.57 for 563. A selection from the 536 inbred had a disease rating of 0.76 compared with the rating of 3.71 for 536. The 563 inbred used in this study was the third successive increase of a self-fertile line that had been selfed three generations. The 536 inbred was the fifth successive increase of another self-fertile line that had been selfed three generations. The results show that variation for *Fusarium* resistance still occurs in 563 and 536 and that substantial gains in resistance can be made through selection within partially inbred lines.

The selection from 563 has been officially released by the U.S. Department of Agriculture and the Beet Sugar Development Foundation under the designation C566. The line was crossed to a closely related CMS in 1978 and the resulting hybrid (566HO) gave a disease rating of 1.63 (Table 3). The first backcross to C566 was made in 1980 and a second backcross accompanied by a selection for stalk-blight resistance will be made in 1981.

Table 3. Progress in selecting for *Fusarium* stalk blight resistance.

Line	Description	No. Plants	Ave.1/ Grade	%2/ Resistant
566	Resistant selection of 563	622	0.30	95
563	S_3 inbred	125	1.57	59
563HO	Cytoplasmic male sterile 563	226	2.49	32
566HO	564H1 x 566	196	1.63	59
564H1	(502HO x 563) x 564	76	3.03	22
502HO	Cytoplasmic male sterile 502	26	1.73	58
536-4	Resistant selection of 536	68	0.76	81
536	S_3 inbred	34	3.71	6
505-32	Sel. from F_2(563aa x 502)	37	0.76	86

1/ Rated on scale of 0 to 4 with 0 = no disease and 4 = dead plant. Grade is average for number of plants observed.
2/ Plants in grades 0 to 1 are considered to be resistant.

Linkage studies: Many of the monogerm inbreds developed in the sugarbeet breeding program at Salinas, California, are susceptible to stalk blight whereas most of the multigerm inbreds tend to be resistant or intermediate. I suspected that there might be a linkage between susceptibility and the monogerm character. Segregating F_2 and backcross populations from hybrids between monogerm and multigerm parents were observed for stalk-blight susceptibility (Table 4) Each monogerm plant and each multigerm plant was graded. Average grades were computed for each multigerm and monogerm population. In four of the populations the stalk-blight grade level was slightly higher for the monogerm plants and in the fifth population the level was slightly higher for the multigerm plants. The differences in stalk blight resistance between paired multigerm and monogerm populations were not statistically significant. The results indicate no close linkage between the monogerm character and stalk-blight susceptibility.

Table 4. Comparison of the *Fusarium* stalk blight resistance of multigerm (MM, Mm) and monogerm (mm) sugarbeet plants in segregating populations.

Line	Description	No. Plts. M-	No. Plts. mm	Ave. Grade 1/ M-	Ave. Grade 1/ mm
802	F_2 (Sus. mm x Res. MM)	178	52	0.26	0.42
803	F_2 (Sus. mm x Res. MM)	176	99	0.14	0.26
804	F_2 (Sus. mm x Res. MM)	138	49	0.08	0.12
105	Sus. mm x (Sus. mm x Res. MM)	150	124	0.48	0.31
103	(Sus. mm x Res. MM) x Sus. mm	144	123	0.81	1.21
	LSD (.05)			NS	

1/ Rated on scale of 0 to 4 with 0 = no disease and 4 = dead plant. Grade is average for number of plants observed.

Inheritance of resistance: The wide range in stalk-blight resistance among breeding lines provided an opportunity to study the mode of inheritance. The highest levels of resistance and susceptibility were found in self-fertile inbred lines. To facilitate hybridization, Mendelian and cytoplasmic male sterile forms of the susceptible 564 inbred were produced and evaluated for stalk-blight resistance. The Mendelian

male sterile 564aa gave a stalk-blight grade of 3.47 with 12 percent resistant plants compared with a grade of 3.97 and 0 percent resistant plants for 564 (Table 5). Although 564aa has a high level of stalk-blight susceptibility, it is not homozygous for susceptibility and is not an ideal parent for use in inheritance studies. The CMS 564HO line has a stalk-blight grade of 3.95 with 0 percent resistant plants and is probably homozygous for susceptibility.

Table 5. *Fusarium* stalk blight resistance of sugarbeet hybrids and their inbred parents.

Line	Description	No. Plants	Ave.[1]/ Grade	%2/ Resistant
554-14	S_{14} of 554 inbred	184	0.01	100
554	Inbred line	125	0.17	98
564	Inbred line	145	3.97	0
564aa	Mendelian male sterile 564	165	3.47	12
564HO	Cytoplasmic male sterile 564	80	3.95	0
563aa	Mendelian male sterile 563	28	3.43	11
104	564aa x 554	353	0.14	97
101	564HO x 554	221	0.30	93
102	(564HO x 554) x 554	202	0.18	97
105	564aa x (564aa x 554)	274	0.41	92
804	F_2(563aa x 554-14)	187	0.09	99
803	F_2(564aa x 554-14)	275	0.18	96
802	F_2(564aa x 554)	230	0.30	89

1/ Rated on scale of 0 to 4 with 0 = no disease and 4 = dead plant. Grade is average for number of plants observed.
2/ Plants in grades 0 to 1 are considered to be resistant.

When 564aa and 564HO were crossed with the resistant 554 inbred, the F_1 progenies graded 0.14 and 0.30 with 97 percent and 93 percent resistant plants, respectively. These results indicated that resistance was dominant. Stalk-blight evaluation tests with F_2 populations of crosses between susceptible and resistant parents showed a high ratio of resistant to susceptible segregates. The proportion of resistant plants in the F_2 populations was especially high (99% and 96%) when the resistant 554-14 line was used as the male parent in crosses with the susceptible 563aa and 564aa lines. When the F_1 (564HO X 554) was backcrossed to the resistant 554 parent, the average grade was 0.18 with 97 percent resistant

plants. When the F_1 (564aa x 554) was backcrossed to susceptible 564aa, the grade was 0.41 with 92 percent resistant plants.

No firm conclusions can be drawn regarding the mode of inheritance. Both the F_2 and backcross data indicate that more than one gene is involved. The lack of homozygosity in the 564aa parent, and variability in *Fusarium* distribution throughout the test field caused problems in correctly interpreting the data. Likewise, root and stalk symptoms are discontinuous and range from a complete lack of symptoms to dead plants. An accurate classification of resistant and susceptible plants was difficult. Additional work including the development of a homozygous susceptible Mendelian male sterile inbred is needed. Supplemental artificial field inoculation with *Fusarium* could be a useful means of reducing field variability.

Even though the mode of inheritance is not fully understood, information obtained in these experiments will be a substantial aid in the planning and conduct of a breeding program. Resistance is definitely dominant and only one parent of a F_1 hybrid needs to be resistant. Progress has been made in selecting resistant monogerm parental lines and their male-sterile equivalents but none of the selections are homozygous for all genes. The inheritance data suggest that further improvements may be possible through additional selection.

SUMMARY

Sugarbeet seed crops grown in the Willamette Valley of Oregon are frequently severely damaged by stalk blight caused by *Fusarium oxysporum* f. sp. *betae*. A wide range in resistance occurs among breeding lines ranging from no injury to death of all plants. The partially inbred lines 562 and 563 that are extensively used as parents in commercial hybrid varieties are susceptible. A resistant selection was made from the 563 line. Resistance was found to be dominant. No close linkage was demonstrated between susceptibility to stalk blight and the monogerm character. Resistance is controlled by more than one gene.

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