Resistance of Biggs Safflower to Phytophthora Root Rot and its Inheritance

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ABSTRACT

The safflower cultivar Biggs possesses a high level of resistance to root rot incited by *Phytophthora drechsleri*. Wound inoculation of hypocotyls of adult greenhouse plants differentiated the high level of resistance of Biggs from lower levels. Performance in field tests indicated that Biggs, unlike other lines and varieties tested, possesses sufficient resistance for production under flood irrigation in some areas. The resistance of Biggs is conditioned by a single recessive factor pair. Phytopathology 60:63-64.

Root rot of safflower, *Carthamus tinctorius* L., incited by *Phytophthora drechsleri* Tucker, was a major disease of irrigated safflower before the development of the moderately resistant cultivars Gila and US 10 (1, 8). These cultivars and certain others with similar resistance are suitable for irrigated culture, provided they are subirrigated or grown on beds and furrow-irrigated for recommended durations (2). They cannot be grown successfully in some areas on heavy, flood-irrigated soils because of *Phytophthora* root rot. Tests with seedling greenhouse plants indicated that Biggs has a higher level of resistance than either Gila or US 10 (7).

Results presented here concern the reaction of adult plants of Biggs and other safflower selections and varieties to *P. drechsleri* under field and greenhouse conditions. The measurement, value, and inheritance of resistance are described.

MATERIALS AND METHODS.—Isolates 201 and 58-11 of *P. drechsleri* were selected on the basis of their selective virulence (7). Inoculum used in greenhouse trials was 3-mm square plugs cut from lima bean agar plate cultures incubated 8 days at 27 C. Inoculum for field tests in Utah consisted of cultures of the isolates grown on moist sterile oats or grain sorghum.

In winter greenhouse trials, plants were grown in steamed soil in porous 8-inch clay pots, four plants/pot. For 3 weeks after emergence, light and dark temperatures of 20 and 15 C were maintained, and no supplemental light was employed. Day and night temperatures then were raised to 25 and 20 C, respectively, and supplemental incandescent light from midnight to 3 AM was used to induce shoot development and flowering. Plants were inoculated 7 weeks after emergence by smearing the inoculum into a 7-mm incision made halfway through the hypocotyl just below the soil surface. The inoculated area was covered with moist steamed soil. Inoculated plants were placed in a greenhouse with a constant air temperature of 30 C for 4 days, and then grown at day and night temperatures of 30 and 25 C until dead or fully mature. Safflower varieties and selections evaluated in previous studies by other methods (7) were used in the greenhouse tests. Forty plants of each were inoculated with each of the two isolates in each of two tests.

Experimental infestation of the soil was employed in field tests from 1963 to 1966 at Logan, Utah. Approximately 1.5 g of inoculum of each isolate/linear 30 cm of row was drilled 8-10 cm deep immediately prior to planting. Seeds were then planted in the same row at 5 cm depth. Biggs, Nebraska 10, Gila, Pacific 7, Ute, and Frio were grown in a modified split-plot design with irrigation treatments as whole plots and varieties and lines as subplots. One 40-hr irrigation, seven 8-hr irrigations, and four 12-hr irrigations were used.

A field test was conducted in 1965 at Woodland, Calif., on soil naturally infested with *P. drechsleri*. The varieties Gila, Frio, Ute, and Biggs were grown in randomized, replicated plots. The field was flood-irrigated 8 weeks after planting with sufficient water to cover the entire plot to a maximum depth of 30 cm. The water remained around the plants for 8 hr. Excess water was removed, and there was none left standing after 18 hr.

In the inheritance study, Biggs was used as the female parent in crosses with the root-rot susceptible cultivar Nebraska 10. Both parents, F_1, F_2, and progenies from backcrosses of F_1 plants to both parents were tested in the greenhouse with isolate 201.

RESULTS.—*Reaction of varieties in greenhouse tests.*—The only external macroscopic reaction of Biggs was the development of a reddish-brown necrotic lesion around the inoculated wounds. Infection was evident 24 hr after inoculation. Ninety-six hr after inoculation, lesions were approximately 2 cm long, and extended one-fourth to one-half way around the hypocotyl. Subsequently, there was little or no enlargement of lesions and no girdling of the hypocotyls. All inoculated Biggs plants survived and fully matured.

Lesion development in Nebraska 10 was similar to that of Biggs for 24 hr after inoculation, but thereafter, lesions expanded rapidly. Within 96 hr, lesions girdled the hypocotyls and extended upwards into the first internode. All inoculated Nebraska 10 plants wilted severely within 120 hr, and subsequently died. Frio, Ute, Gila, US 10, Pacific 7, Utah 1421-9-16, and Nebraska 4051 developed lesions more slowly than Nebraska 10, but all plants of these lines died before maturity.

TABLE 1. Mortality of six safflower cultivars 12 weeks after planting on soil experimentally infested with *Phytophthora drechsleri* and subjected to three different irrigation treatments

Safflower Var.	One 40-hr irrigation	Seven 8-hr irrigations	Four 12-hr irrigations
	%	%	%
Nebraska 10	89[a]	89	61
Gila	66	24	4
Pacific 7	70	7	2
Ute	68	5	1
Frio	38	15	1
Biggs	2	0	0

[a] Average per cent mortality in 3 successive years, 1963-1966, at Logan, Utah.

No difference in virulence between isolates 201 and 58-11 was discernible on Nebraska 10. Although, with the exception of Biggs, both isolates killed all plants prior to maturity, isolate 201 appeared slightly more aggressive.

Reaction of varieties in field tests.—The resistance of Biggs was outstanding in the tests at Logan, Utah (Table 1). Only Nebraska 10 was susceptible in the lightest irrigation treatment. Although Gila, Pacific 7, Ute, and Frio were resistant or moderately resistant in two of the irrigation treatments, they were less so than Biggs when exposed to single 40-hr irrigation.

At Woodland, Calif., less than 1% of the Biggs plants were killed. Gila and Frio were susceptible, with 100% of the plants infected in some areas of the plots and approximately 50% of the plants in an entire plot killed. An average of 15% of the Ute plants were killed, indicating an intermediate level of resistance.

Inheritance.—The F_1 plants of the cross Biggs × Nebraska 10 were as susceptible as the susceptible parent. The segregation ratio for *Phytophthora* root rot susceptibility and resistance was in good agreement to a 3:1 ratio (Table 2). Data obtained from backcrossing F_1 plants to each parent substantiated the hypothesis that resistance is conditioned primarily by a single-factor pair exhibiting complete recessiveness. The gene pair in Biggs which conditions resistance is designated ph_1 ph_1.

DISCUSSION.—Biggs has a higher level of resistance than any other line tested. The greenhouse inoculation procedure of this study was more precise than those employed previously (4, 6, 7), inasmuch as it clearly differentiated the Biggs level of resistance from all lower levels. Also, the method proved particularly feasible when we desired seed production by resistant plants.

Although Biggs withstood the disease in our flood-irrigations, we believe that longer periods of standing water would cause drowning. Biggs safflower is not suitable for commercial production because of its late maturity and low oil content of the seed. It is useful as a source of resistance in a breeding program.

TABLE 2. Reaction of resistant Biggs and susceptible Nebraska 10, the F_1 hybrid, F_2, and backcross populations to *Phytophthora drechsleri*

Parent or cross	Plants[a]		Chi-square	P value
	Resistant	Susceptible		
	no.	*no.*		
Biggs	100	0		
Nebraska 10	0	100		
Biggs × Nebraska 10 F_1	0	100		
F_2	111	366	0.76[b]	0.70[b]
F_1 × Biggs F_1	120	130	0.40	0.50[c]
F_1 × Nebraska 10 F_1	0	100		

[a] Seven-week-old greenhouse plants inoculated with isolate 201.
[b] Goodness of fit to a 3:1 ratio.
[c] Goodness of fit to a 1:1 ratio.

Pathogenic races of *P. drechsleri* exist (7), and Biggs is resistant to all known races, whereas Gila and US 10 each possess resistance to only one pathogenic race. Both Gila and US 10 were developed by crossing Nebraska 10 and Western Oilseeds 14 with subsequent backcrosses to Nebraska 10 (3, 5, 8). Reaction of the backcross progenies in screening tests for the selection of resistant plants indicated that resistance of these two varieties resulted from a single dominant gene from Western Oilseeds 14. The results presented here show that resistance of Biggs is caused by a single recessive factor pair. Resistance of safflower to *P. drechsleri* apparently is genetically complex.

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