# Inheritance of Resistance to *Puccinia graminis* f. sp. *secalis* in Barley

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**ABSTRACT**

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Resistance of Black Hull-less barley (*Hordeum vulgare*) to *Puccinia graminis* f. sp. *secalis* was studied in crosses with susceptible cultivars Larker, Beacon, and Glenn. Segregation ratios of $F_2$ plants and $F_3$ families were consistent with the segregation of a single gene with the recessive allele conferring resistance.

*Puccinia graminis* Pers. f. sp. *secalis* is occasionally found on commercially grown barley (*Hordeum vulgare* L.) in the Red River Valley of Minnesota and North Dakota. Although not a serious problem, this pathogen presents a potential threat to barley production because some isolates are virulent on many barley cultivars (8). Only a few studies have been made on the inheritance of resistance of barley to *P. graminis* f. sp. *secalis*. Babriwala (2) and Luig (5) studied it in Purple Nudum and Skinless barley and reported a single dominant gene for resistance, although Luig also found evidence for modifying genes. The inheritance of resistance to *P. graminis* f. sp. *tritici* in barley has been investigated by a number of workers and reviewed by Smith (7). The objective of this study was to investigate the inheritance of resistance to *P. graminis* f. sp. *secalis* in barley.

## MATERIALS AND METHODS

The source of resistance studied was Black Hull-less, which was reported resistant to *P. graminis* f. sp. *secalis* by Johnson and Buchannon (4), Barbriwala (2), and Luig (5) and confirmed in our field tests at Rosemount, MN (8). The $F_2$ seed of the crosses Black Hull-less/Larker, Black Hull-less/Beacon, and Black Hull-less/Glenn were obtained through the courtesy of R. G. Timian and J. D. Franckowiak.

$F_2$ plants of the three crosses were evaluated in the greenhouse. The susceptible parents and 30–272 $F_2$ plants of each cross were grown in the greenhouse at about 20 C, and when day length was less than 12 hr/day, additional illumination (11,000 lux) was provided by fluorescent tubes. Black Hull-less was grown in a greenhouse at about 14 C with supplemental light (11,000 lux) provided by fluorescent tubes for 16 hr/day to induce heading. Two weeks after planting, 3.5 g of benomyl per 3.7 L of $H_2O$ was applied as a soil drench at a rate of about 20 ml/pot to protect the plants against powdery mildew (*Erysiphe graminis* DC.). Plants were fertilized 3 wk after planting with a water-soluble formula (23-19-17, NPK) applied at a rate of 1.4 g/pot.

Race HQ (Cereal Rust Laboratory isolate 76-32-1355) of *P. graminis* f. sp. *secalis* was used in this experiment because it had been virulent on most barley cultivars tested in the field. Urediospores for inoculation were increased, stored, and prepared for inoculation using procedures described by Steffenson (9). Plants at the kernel-fill stage of growth were quantitatively inoculated using the device of Andres (1), set to operate at 15 cm/sec with the spray nozzle 12 cm from the plants. A concentration of about 2.46 mg of urediospores per 8 ml of lightweight mineral oil was applied at a rate of about 0.08 ml of oil per stem.

After inoculation, plants were placed overnight in a dark dew chamber at $20 \pm 2$ C. At 0800 hours, the dew chamber was illuminated with three metal arc bulbs. Light intensity was 9,700–12,900 lux on the inoculated portions of the culm. At 1030 hours, the chamber door was opened to allow the plants to slowly dry off. When the plants were dry, they were taken from the dew chamber, fertilized (23-19-17, NPK) at a rate of 1.4 g/pot, and placed in a greenhouse at about 18 C, where additional light (11,000 lux) was provided by fluorescent tubes when day length was less than 12 hr/day. Three weeks after inoculation, the host-pathogen disease interaction on the lower half of the flag leaf sheath was recorded. On this tissue, plants considered resistant had small uredia (shorter than 2.5 mm) associated with necrosis or chlorosis, whereas plants considered to be susceptible had large (longer than 2.5 mm) erumpent uredia without chlorosis.

About 40 seeds from individual $F_2$ plants of the crosses were planted in the field at Rosemount, MN. Some $F_2$ plants of each cross were sterile so progenies from all $F_2$ plants could not be tested in the $F_3$. The $F_3$ families were planted within a rye stem rust nursery in 1.2-m rows spaced 32 cm apart. Seed of each parent were also planted in the nursery. To initiate an epidemic of stem rust, spreader rows of the susceptible cultivar Prolific rye were inoculated by injecting the stems with 1.0 g of urediospores per 5 L of $H_2O$. Also, the parents, $F_3$, and spreader-row plants were sprayed directly with a backpack mist-blower using 0.2 mg of uredospores per milliliter of lightweight mineral oil at a rate of about 1.6 ml of oil per meter of row when most entries were in the heading stage of growth. Weather conditions at inoculation favored stem rust infection. When plants were in the dough stage of growth, the host-pathogen interaction on the flag leaf sheath was recorded as with plants tested in the greenhouse.

## RESULTS

The reactions of the parents to *P. graminis* f. sp. *secalis* (isolate 76-32-1335) are listed in Table 1. Black Hull-less was resistant, whereas Larker, Beacon, and Glenn were susceptible.

**Table 1.** Reaction of parents involved in three crosses with Black Hull-less infected with isolate 76-32-1335 of *Puccinia graminis* f. sp. *secalis*

| Parent | Response class[a] | No. of plants examined |
|---|---|---|
| Black Hull-less | Resistant | 36 |
| Larker | Susceptible | 24 |
| Beacon | Susceptible | 23 |
| Glenn | Susceptible | 24 |

[a] Resistant class: uredia minute to small (shorter than 2.5 mm), with a sharp necrotic border or much chlorosis. Susceptible class: uredia medium to large (longer than 2.5 mm), with or without some chlorosis.

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With both the parents and $F_2$ progeny, the resistant and susceptible classes could be best distinguished on the lower half of the flag leaf sheath. On this tissue, the resistant plants carried small uredia associated with necrosis or chlorosis, whereas susceptible plants carried large erumpent uredia without chlorosis. The uredia were smaller near the peduncle on both resistant and susceptible plants. In some cases, host responses typical of those found on the bases of the flag leaf sheaths of resistant plants were present near the peduncles of susceptible plants.

The segregation ratios of adult $F_2$ plants of the crosses Black Hull-less/Larker, Black Hull-less/Beacon, and Black Hullless/Glenn in the greenhouse are shown in Table 2. In each cross, the data were consistent with the segregation of a single gene with the recessive allele conferring resistance. The data of the $F_3$ families of each cross tested in the field are given in Table 3. In each cross, the goodness-of-fit probability was satisfactory for a 1:2:1 ratio of resistant:segregating:susceptible plants.

**Table 2.** Numbers of susceptible and resistant adult $F_2$ progeny of three crosses involving Black Hull-less infected with isolate 76-32-1335 of *Puccinia graminis* f. sp. *secalis* in the greenhouse

| Cross | Number of plants | | $\chi^2$ | Probability[a] |
|---|---|---|---|---|
| | Susceptible | Resistant | (3:1) | |
| Black Hull-less/Larker | 22 | 8 | 0.04 | 0.75–0.95 |
| Black Hull-less/Beacon | 25 | 5 | 1.11 | 0.30–0.25 |
| Black Hull-less/Glenn | 196 | 76 | 1.25 | 0.30–0.25 |

[a] Probability of a greater $\chi^2$ value.

**Table 3.** Numbers of resistant, segregating, or susceptible $F_3$ families of three crosses involving Black Hull-less infected with isolate 76-32-1335 of *Puccinia graminis* f. sp. *secalis* in the field

| Cross | Number of families | | | $\chi^2$ | Probability[a] |
|---|---|---|---|---|---|
| | Resistant | Segregating | Susceptible | (1:2:1) | |
| Black Hull-less/Larker | 8 | 9 | 8 | 1.96 | 0.50–0.30 |
| Black Hull-less/Beacon | 5 | 8 | 10 | 4.30 | 0.20–0.10 |
| Black Hull-less/Glenn | 24 | 61 | 20 | 3.02 | 0.20–0.10 |

[a] Probability of a greater $\chi^2$ value.

## DISCUSSION

The resistant and susceptible classes for parents and progeny in our tests were easily recognized, and data of the three crosses strongly support the conclusion that a single recessive gene governs resistance to isolate 76-32-1335 of *P. graminis* f. sp. *secalis* in Black Hull-less. Most single host genes that condition rust resistance to the genus *Puccinia* are dominant, but the occurrence of single recessive genes is not rare. Hooker (3) cited six host-parasite systems where single recessive genes were involved.

From the $F_3$ field data, resistant, segregating, and susceptible families were identified. Resistant families were easily recognized, but a few susceptible plants were found in a few of them. Because the resistant families should have been homozygous recessive, no segregation was expected. Because Black Hull-less had no susceptible plants observed, we suggest that the susceptible plants in the resistant families probably resulted from a seed mix or an outcross. The $F_3$ data support the hypothesis of a 1:2:1 resistant:segregating:susceptible ratio, but the number of plants in the segregating class was somewhat low in two crosses. One possible reason for this may be that five $F_2$ plants of Black Hull-less/Larker and seven $F_2$ plants of Black Hull-less/Beacon, all of the susceptible class, were sterile; hence, no $F_3$ seed was taken to the field. If there was a tendency for susceptible or segregating plants to be sterile, this could explain the smaller number of families in the segregating category in the $F_3$ data.

Powers and Hines (6) designated the stem rust resistance gene in Peatland as the T gene. The letter "T" was taken from *tritici* because Peatland was resistant to that forma specialis of *P. graminis*. To continue this tradition, the recessive gene in Black Hull-less that conditions resistance to *P. graminis* f. sp. *secalis* will be tentatively designated as the "S" gene. It should be relatively easy to manipulate this gene in programs breeding for rust resistance; however, more work should be done to test the reaction of cultivars that possess the S-gene to a number of isolates of *P. graminis* f. sp. *secalis*. In another experiment, we found Black Hull-less was resistant in the field when inoculated with a composite of 10 races of *P. graminis* f. sp. *secalis*. In addition to Black Hull-less, Valkie, Abyssinian, Hispont, and Heitpas 5 were also resistant to this composite of races.


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