# Inheritance of Blast Resistance in Two-Rowed Barley

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**ABSTRACT**

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Twelve of 24 cultivars of two-rowed barley were resistant to one isolate of the blast fungus (*Pyricularia grisea*) from barley, and 12 were susceptible. All cultivars were susceptible to two other isolates of *P. grisea* (one from barley and one from crabgrass) and to one isolate of *P. oryzae* from rice. Genetic analysis indicated that each of the resistant cultivars, Daisen Gold and Miho Golden, has a single dominant gene conditioning resistance to the barley isolate. This gene was designated as *PHR-1*. This is the first report confirming a gene for blast resistance in barley.

Blast caused in two-rowed barley (*Hordeum distichum* L. emend Lam.) by *Pyricularia oryzae* Cavara was first reported by Kawai et al (4) and Matsumoto and Mogi (5) in 1979. In these papers, a varietal difference in the incidence of barley blast had been described, but the reports were all based on naturally occurring blast in the field. Therefore, no precise information was available on blast resistance in barley. Okada and Yaegashi (6) found blast on two-rowed barley sown in late summer in 1980 and showed that blast isolates from barley produced perithecia in their mutual crosses in petri dishes. Although the barley isolates we obtained were different from the above-mentioned *P. oryzae*, these isolates seemed to be suitable for identifying the factor(s) conditioning blast resistance in two-rowed barley because of their cross-fertility and pathogenic differences to the cultivars of barley. Genetic studies of the barley cultivar and the barley blast fungus will provide useful information for developing cultivars with lasting resistance.

The present study was undertaken to evaluate the resistance of two-rowed barley to the blast fungus and to determine the mode of inheritance of blast resistance.

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## MATERIALS AND METHODS

**Host.** Twenty-four cultivars of two-rowed barley were obtained from the National Agricultural Research Center and Tochigi Prefectural Agricultural Experiment Station. Four cultivars of two-rowed barley were selected as host samples for genetic analysis because of their differential reactions to the blast isolates used. Barley plants for inoculation were grown in seedling cases (15 × 5 × 10 cm) in a greenhouse until the one-and-one-half to two-leaf stage. Plants for crossing or selfing were grown in 1/25 $m^2$ Wagner's pots in the screenhouse. The following crosses were made: Daisen Gold × Saikai Kawa 24; Miho Golden × Fuji Nijo II; and Miho Golden × Daisen Gold. Reciprocal crosses were also made to test for cytoplasmic factors involved in blast resistance. The $F_1$ or $F_2$ seeds resulting from a cross or selfing were harvested from plants at maturity.

**Fungus.** Monoconidial isolates M80-25 (mating type a) and M80-32 (mating type A) of *Pyricularia grisea* (Cke.) Sacc. (*Magnaporthe grisea* (Hebert) Barr) from barley plants in Miyazaki prefecture in 1980 (6) were used for genetic analysis of blast resistance. Mating type and pathogenicity of blast isolates to two-rowed barley are indicated in Table 1. In addition to the monoconidial isolates, Ken60-19 (mating type a) of *P. oryzae* from rice and Ken81-6 (mating type A) of *P. grisea* from crabgrass were used for evaluating the blast resistance of all cultivars of barley.

**Inoculation and evaluation.** Since host reaction to the blast fungus varied slightly with the leaf stage of barley, test plants were all inoculated at the one-and-one-half to two-leaf stage by spraying a conidial suspension containing $5 \times 10^5$ to $1 \times 10^6$ spores per milliliter onto the leaves. Inoculated plants were incubated in a moist chamber at 26–28 C for 20 hr, and then transferred to the greenhouse. Ratings were made 5–6 days after inoculation. Plants that showed large whitish lesions (W or pW type) or eye-spots with brown margins (bG type) were classified as susceptible. Plants that showed no lesions or brown pinpoint lesions (b type) were classified as resistant (Fig. 1).

**Table 1.** Reaction of two-rowed barley to *Pyricularia* isolates from barley

| | Blast isolate | |
|---|---|---|
| **Barley cultivar** | **M80-25(a)**[a] | **M80-32(A)** |
| Daisen Gold | R[b] | S |
| Miho Golden | R | S |
| Saikai Kawa 24 | S | S |
| Fuji Nijo II | S | S |

[a] Letter in parenthesis indicates mating type.
[b] Reaction type: R = resistant and S = susceptible.

## RESULTS

Twenty-four cultivars of two-rowed barley were inoculated with the four isolates of blast pathogen. Reactions of the two-rowed barley cultivars varied with the combinations of barley cultivars and blast isolates. All of the cultivars of two-rowed barley were susceptible to rice isolate Ken60-19, crabgrass isolate Ken81-6, and one barley isolate (M80-32) but only 12 cultivars were susceptible to the barley isolate M80-25 (Table 2). Of 12 cultivars resistant to the barley isolate M80-25, two cultivars, Daisen Gold and Miho Golden, were selected and crossed with the susceptible cultivars Saikai Kawa 24 and Fuji Nijo II for genetic analysis of blast resistance. The $F_1$ plants from the crosses of Daisen Gold $\times$ Saikai Kawa 24 and Miho Golden $\times$ Fuji Nijo II were all resistant to the isolate M80-25, which indicated that a dominant gene or genes were responsible for resistance. To determine the mode of inheritance of blast resistance, 20 $F_1$ plants from each of the crosses of Daisen Gold $\times$ Saikai Kawa 24, Miho Golden $\times$ Fuji Nijou II, and Miho Golden $\times$ Daisen Gold were selfed and the resulting $F_2$ progenies were inoculated with spore suspensions of isolate M80-25 (Table 3). The $F_2$ families from crosses of resistant with susceptible cultivars segregated in a ratio of 3 resistant:1 susceptible. The results indicate that each of the two cultivars, Daisen Gold and Miho Golden, has a single dominant gene conditioning resistance to the blast isolate M80-25. The $F_2$ family from the cross of Daisen Gold $\times$ Miho Golden did not segregate in resistance (i.e., the cross between two resistant cultivars did not yield any susceptible plants). A possible explanation to account for these data is that Daisen Gold and Miho Golden have the same dominant gene for resistance to blast isolate M80-25. This is designated here as *PHR-1*. Reciprocal crosses between the resistant and susceptible cultivars indicated no maternal cytoplasmic influence (Table 3). In the inoculation tests with the isolate M80-32, however, all plants of $F_1$ and $F_2$ families from the crosses between four barley cultivars were susceptible.

To get information on the genealogical source of resistance gene *PHR-1*, the host reaction of the ancestry of Daisen Gold and Miho Golden was evaluated by inoculation (Fig. 2). Of nine cultivars tested, seven were determined to be resistant to the blast isolate M80-25, and the other two were susceptible. Since there is a possibility that Golden Melon or Svanhals is the origin of the resistance gene *PHR-1*, the pedigree of all resistant cultivars of two-rowed barley was investi-

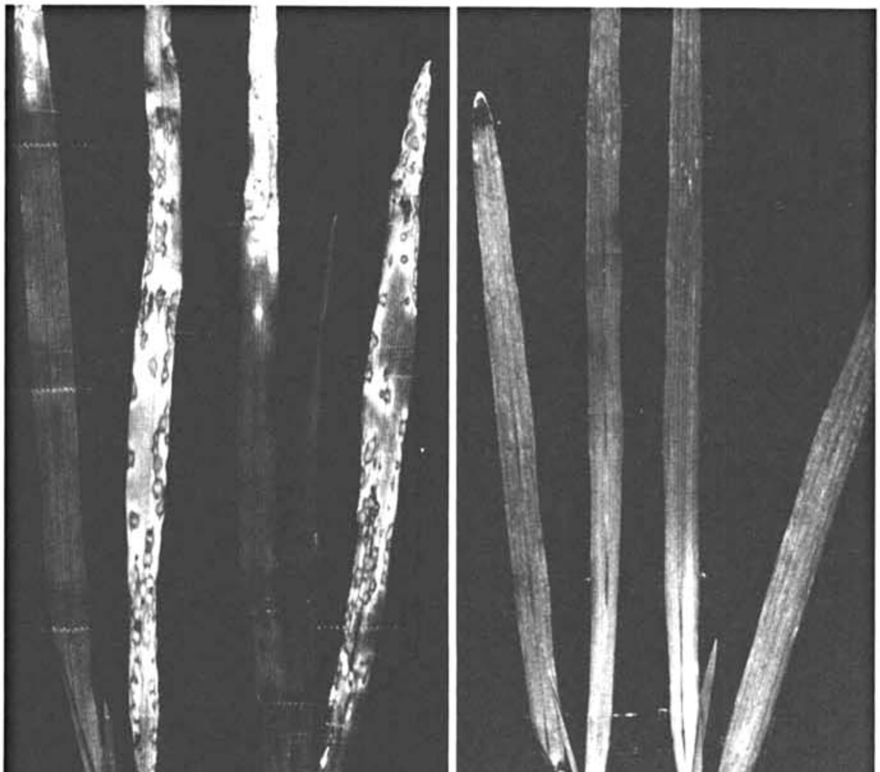


**Fig. 1.** Host reaction of two-rowed barley to *Pyricularia* isolate M80-25: **(A)** Susceptible reaction of Saikai Kawa 24 and **(B)** resistant reaction of Daisen Gold.

**Table 2.** Reactions of two-rowed barley cultivars to *Pyricularia* isolates from barley

| | Blast isolate | |
|---|---|---|
| **Barley cultivar** | **M80-25**[a] | **M80-32**[a] |
| Nyu Golden (G)[b] | R[c] | S |
| Azuma Golden (G) | R | S |
| Daisen Gold (G) | R | S |
| Miho Golden (G,S) | R | S |
| Kawahonami (G) | R | S |
| Kawamizuki (G) | R | S |
| Saikai Kawa 21 (G,S) | R | S |
| Saikai Kawa 35 (G) | R | S |
| Kyushu Nijo 4 (G) | R | S |
| Kyushu Nijo 5 (G) | R | S |
| Taichung Nijoomugi * | R | S |
| Hoshimasari (S) | R | S |
| Kawasaigoku | S | S |
| Saikai Kawa 19 | S | S |
| Saikai Kawa 22 | S | S |
| Saikai Kawa 24 | S | S |
| Saikai Kawa 34 | S | S |
| Kanto Nijo 19 | S | S |
| Kanto Nijo 20 | S | S |
| Haruna Nijo | S | S |
| Amagi Nijo | S | S |
| Akagi Nijo | S | S |
| Fuji Nijo II | S | S |
| Satsuki Nijo | S | S |

[a] *Pyricularia grisea* from barley.
[b] G = Golden Melon in ancestry, S = Svanhals in ancestry, * = unknown.
[c] Reaction type: R = resistant and S = susceptible.

gated to conjecture which cultivar is involved. It was revealed that almost all resistant cultivars had Golden Melon in common in their ancestry (Fig. 2).

## DISCUSSION

The blast isolates obtained from two-rowed barley were not pathogenic to rice and were definitely different from rice blast fungus (*P. oryzae*), reported as a causal agent of blast disease of barley (4,5). In 1980, the blast disease had occurred on not only two-rowed barley but also Italian ryegrass (*Lolium multiflorum* Lam.) in the same area of Miyazaki prefecture. So there is a possibility that the blast fungus of ryegrass might be an inoculum source of the barley blast. However, it is not always easy to identify the causal agent of ryegrass blast because of the fact that ryegrass is susceptible to most *Pyricularia* species (8). Carver et al (3), Bain et al (1), and Trevathan (7) reported the blast disease of ryegrass and treated its causal pathogen as *Pyricularia* sp. or *P. grisea*. The blast isolates from barley and *P. grisea* from ryegrass from Trevathan were compared and no differences in host range or morphological characters were found (6). Both of the blast isolates incited susceptible lesions on barley, ryegrass, tall fescue, and some other hosts, but not on crabgrass and rice. Although the inclusion of blast isolates nonpathogenic to crabgrass in *P. grisea* was open to question, the blast fungus from two-rowed barley was tentatively treated as *P. grisea* because of a close similarity in morphology of the fungus to crabgrass. The perfect stage of the barley blast fungus was morphologically identified as *Magnaporthe grisea* (2,6,9).

Varietal differences in the incidence of barley blast had been observed in field tests (4,5), but no precise information was available on the resistant cultivar developing the brown pinpoint lesions only. In the present study, however, it was recognized for the first time that 12 out of 24 cultivars of two-rowed barley used were quite resistant to one isolate of blast from barley. Moreover, it was revealed from the survey of the parentage that 10 out of the 12 resistant cultivars had Golden Melon in common in their ancestry. In addition, three resistant cultivars had Svanhals in their ancestry. These results seemed to indicate a possibility that the gene for blast resistance (*PHR-1*) might be derived from Golden Melon, introduced from Australia in 1881. Additional genes for blast resistance will probably be detected in the future by using different isolates and barley cultivars.

**Table 3.** Segregation for resistance to *Pyricularia* isolate M80-25 in the $F_2$ families from the five crosses of barley cultivars

| Cross | Number of progeny | | *P* value from chi-square test |
|---|---|---|---|
| | Resistant | Susceptible | (3:1) |
| Daisen Gold (R)[a] × Saikai Kawa 24 (S) | 318 | 109 | 0.8–0.9 |
| Saikai Kawa 24 (S) × Daisen Gold (R) | 354 | 123 | 0.5–0.7 |
| Miho Golden (R) × Fuji Nijo II (S) | 335 | 113 | >0.9 |
| Fuji Nijo II (S) × Miho Golden (R) | 329 | 113 | 0.7–0.8 |
| Miho Golden (R) × Daisen Gold (R) | 487 | 0 | ... |

[a] R = resistant cultivar and S = susceptible cultivar.

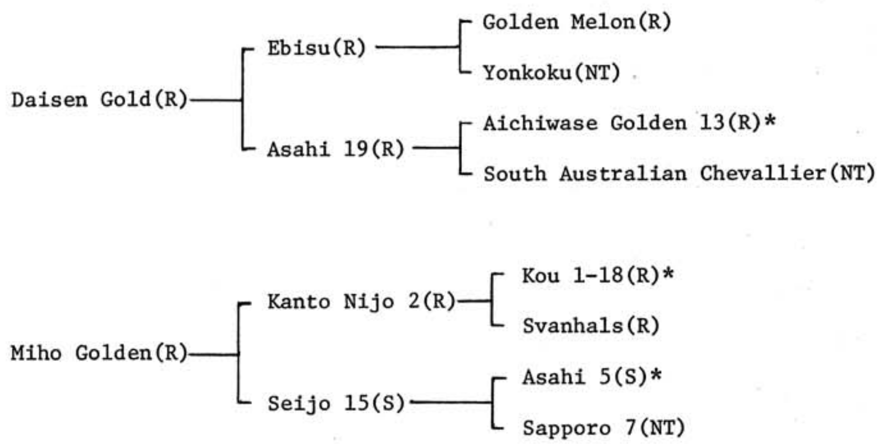


**Fig. 2.** Pedigree of Daisen Gold and Miho Golden and their host reactions to *Pyricularia* isolate M80-25. (R) = Resistant, (NT) = not tested, no seeds obtained, (S) = susceptible, and * = derived from Golden Melon.

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