

Sources of Genes Resistant to *Puccinia hordei* in Barley

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ABSTRACT

Sharp, E. L., and Reinhold, M. 1982. Sources of genes resistant to *Puccinia hordei* in barley. Plant Disease 66:1012-1013.

A total of 178 barley (*Hordeum vulgare*) cultivars or lines were evaluated to 12 isolates of *Puccinia hordei* from the United States and the Mediterranean area. The genes Pa₃ and Pa₇ of barley were effective against all 12 isolates. Two lines of barley apparently not possessing either the Pa₃ or Pa₇ gene were also resistant to all cultures of *P. hordei*. The Pa₉ gene in the barley line CI 1243 was overcome by only one isolate of *P. hordei* from Israel, which originated from the alternate host (*Ornithogalum* sp.). Differences in infection types with cultivars reported to carry the gene Pa₂ indicated the presence of more than one gene. Twenty-eight potentially useful resistance sources effective against more than 50% of the isolates were detected. Several cultivars contained resistance genes apparently different from any Pa gene previously described.

Additional key words: barley leaf rust

In contrast with cereal rusts of wheat (*Triticum aestivum* L.) and oats (*Avena sativa* L.), little emphasis has been placed to date on the determination and use of gene sources in barley (*Hordeum vulgare* L.) resistant to *Puccinia hordei* Otth., which incites a leaf rust. The disease, however, represents a serious threat to barley production in the Mediterranean basin and has recently increased in importance in northwestern Europe. The improved control of other leaf diseases developing earlier in the season in Europe has increased the competitive ability of *P. hordei*, which occurs later in the season (4,7). Leaf rust is also widespread in the United States and may cause severe damages to the crop in the eastern and southern parts of the country (8).

Previous evaluations of resistance sources resulted in the description of nine genes, Pa-Pa₉, resistant to *P. hordei* (8,9,12,13). The most extensive studies on available resistance gene sources in barley have been conducted in East Germany (4). In addition to cultivars carrying the different Pa genes, a number of other resistance gene sources to *P. hordei* were detected. These resistance gene sources originated mainly from land cultivars of barley of the Mediterranean area and Ethiopia. Considerable resistance to the pathogen also occurs in collections of *H.*

spontaneum Koch, a wild ancestor of cultivated barley. *H. spontaneum* was also resistant to isolates of the fungus from Israel (1). Although no concerted efforts have been made in western Europe to breed for resistance to *P. hordei*, many cultivars with partial resistance (slow rusters) have been detected (5).

In this study, many cultivars previously reported to be resistant to *P. hordei* were evaluated to isolates of the fungus from semiarid environments. The results should be of particular value to local barley breeders as well as to breeding programs developing broad-based resistance to *P. hordei* in barley (10).

MATERIALS AND METHODS

Seed of 178 barley cultivars and lines evaluated for reaction to *P. hordei* was obtained from several sources. Seed of 27 barley cultivars or lines was collected by the first author at Sakha, Egypt, in 1979. The remaining 151 barley cultivars and lines that were evaluated originated from the barley collection at Montana State University, Bozeman, or were obtained from various barley workers.

Eight to 10 plants per cultivar or line were evaluated with 12 different isolates of *P. hordei*. Collection sites, isolation and increase of the fungus, as well as inoculation techniques and evaluation of host reaction are given in another paper (6).

RESULTS

Among the 178 cultivars or lines tested, seven were resistant to all isolates of *P. hordei* (Table 1). Five of these carried either the gene Pa₇ or Pa₃ (4,14). Two lines (Giza × 117 × Bakhim × Giza 118 × FAO 86 and Giza 119 × Tanekasse 105) probably represent previously undescribed genotypes. The observed infection type with the Pa₇ gene in barley was always 0

(no visible pustules), with concomitant, very distinct necrotic areas at the infection sites (6). A number of cultivars or lines represent good sources of resistance to *P. hordei* (Table 2), even though they were not effective against all 12 isolates of the fungus investigated in this study. Cultivars reportedly possessing the Pa₂ gene or a complex involving this gene (Peruvian, Batna, Ariana, Bolivia, Weider) often expressed different infection types to *P. hordei* (Table 2).

The lack of resistance in barley to the highly virulent isolates from Sidney, MT, (isolate 2) and Sakha, Egypt, (isolate 8) is obvious (Table 2). Only 4 and 5 cultivars, respectively, were found to be resistant or intermediate to these isolates of *P. hordei* as compared with 11 or more cultivars with resistance gene sources to the other 10 isolates. The Pa₉ gene in CI 1243 showed broadly based resistance to *P. hordei* and gave a resistant or intermediate reaction or low infection type with most isolates (6). With the Tel Aviv isolate (isolate 9), however, a susceptible reaction or high infection type was observed on cultivars carrying the Pa₉ resistance gene (Table 2).

DISCUSSION

Current knowledge on sources of resistance to *P. hordei* is limited to cultivars and lines reportedly carrying one or two of the known Pa genes. Although none of these genes has been used extensively in breeding programs in barley, virulence to the Pa, Pa₂ (and its complex), and Pa₄ genes in the host

Table 1. Cultivars and lines of barley resistant to 12 different isolates of *Puccinia hordei*

Cultivar or line	Host Pa gene ^b
Aim (CI 3737)	Pa ₃
Cebada Capa (CI 6193)	Pa ₇
Estate (CI 3410)	Pa ₃
Forrajera Klein × Rika 7 (CI 11801)	Pa ₇
La Estanzuela	Pa ₇
Giza 117 × Baktim × Giza 118 × FAO 86	Unknown
Giza 119 × Tanekasse 105	Unknown

^aIsolate 1: Creston, MT, USA; 2: Sidney, MT, USA; 3: San Antonio, TX, USA; 4: Rabat, Morocco; 5: Merchouch, Morocco; 6: Marrakech, Morocco; 7: Fretissa, Tunisia; 8: Sakha, Egypt; 9: Tel Aviv, Israel; 10: Tel Hadia, Syria; 11: Hqms, Syria; and 12: Izmir, Turkey.

^bAuthority for known host genes is Walther and Lehmann (14).

Contribution from the Montana Agricultural Experiment Station. Journal Series Paper 1196. Supported in part by AID contract DSAN-C-0024.

Accepted for publication 24 February 1982.

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0191-2917/82/11101202/\$03.00/0
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Table 2. Sources of resistance in barley to *Puccinia hordei*

Cultivar or line	Pa gene	Isolate ^a											
		1	2	3	4	5	6	7	8	9	10	11	12
Resistant or intermediate to 7 isolates^b													
San Carlos (CI 11533)		I	I	S	R	R	S	S	I	S	S	I	R
Badajoy (CI 7480)		R	S	R	R	R	R	I	S	S	S	S	I
CI 8612		R	S	R	I	I	S	R	S	R	S	S	R
Batna (CI 3391)	Pa ₂ +	R	S	I	I	R	R	S	S	S	I	S	I
Modjo (CI 14048)		I	S	S	I	I	I	S	S	I	S	I	I
Hybernum Hor 728 (CI 11577)		R	S	S	S	R	R	R	S	R	I	S	I
Sudan (CI 6489)	Pa	S	S	R	I	R	I	R	S	R	S	I	S
Peruvian (CI 935)	Pa ₂	S	S	R	S	R	I	I	S	I	I	S	I
Resistant or intermediate to 8 isolates													
Athenais × Nopal 'S'		R	S	R	R	R	I	I	S	R	R	S	S
Athenais		S	S	R	I	R	R	R	R	R	I	S	S
CI 3634		S	S	S	R	R	I	R	S	R	I	R	I
Resistant or intermediate to 9 isolates													
Ariana (CI 2524)	Pa ₂	I	I	I	I	I	R	S	S	I	I	S	I
Bolivia (CI 1257)	Pa ₂ + Pa ₆	I	I	I	I	S	R	I	I	I	S	I	S
Weider (CI 1021)	Pa ₂	R	S	I	I	I	I	I	S	I	I	I	S
Mari × Athenais		I	S	R	I	R	R	R	S	R	R	S	R
Gizeh 134		I	S	R	I	R	R	R	S	R	R	S	R
CI 4978		R	S	R	I	I	R	S	S	I	I	I	R
Resistant or intermediate to 10 isolates													
Praecox mass sel. (CI 4974)		I	S	R	I	R	I	I	R	R	R	S	I
CCIM-13		R	S	R	I	I	I	R	I	R	S	I	I
Ford 1203		I	S	R	I	I	R	R	S	R	I	R	I
Resistant or intermediate to 11 isolates													
Hor 2596 (CI 1243)	Pa ₉	R	I	I	I	I	I	R	I	S	I	I	R

^a Isolate 1: Creston, MT, USA; 2: Sidney, MT, USA; 3: San Antonio, TX, USA; 4: Rabat, Morocco; 5: Merchouch, Morocco; 6: Marrakech, Morocco; 7: Fretissa, Tunisia; 8: Sakha, Egypt; 9: Tel Aviv, Israel; 10: Tel Hadia, Syria; 11: Homs, Syria; and 12: Izmir, Turkey. Cultures are more fully described in Reinhold and Sharp (6) and are available from the authors.

occurs quite frequently among collections of *P. hordei* from Europe and the United States (13). The host genes Pa₃ and Pa₉ are reported to be effective against a broad spectrum of virulence types in *P. hordei*. However, isolates of *P. hordei* virulent to the Pa₃ and Pa₉ genes occur in Great Britain (2) and in Germany (13). The Pa₃ gene, represented in the barley cultivars Aim and Estate, was found to be effective against all isolates from the United States and the Mediterranean area. The Pa₉ gene in CI 1243 was overcome by only one isolate, which originated in Israel from the alternate host (*Ornithogalum* sp.). The alternate host has also been implicated in the development of a new virulent strain of *P. hordei* able to overcome resistance of the Pa₇ gene (3). The Pa₇ gene, which occurs in several cultivars, was effective against all isolates and represented a potential source for resistance to *P. hordei*. The Pa₇ gene from the cultivar Cebada Capa has recently been incorporated into the U.S. cultivars Henry and Monroe (11). As observed earlier (13,14), this research indicated the presence of different genes in cultivars reportedly carrying the Pa₂

gene or Pa₂ and an additional gene for resistance to *P. hordei*.

In addition to the known Pa genes, a number of useful resistance sources were detected. Two related lines were found to be resistant to all isolates. Their pedigrees and identical infection types suggest identical genotypes for resistance to *P. hordei*. As opposed to the Pa₃ and Pa₇ genes, these lines did not exhibit extensive chlorosis or necrosis. Fourteen previously undescribed genotypes resistant to more than 50% of the isolates establish the availability of good resistance sources to *P. hordei* in barley collections. Some of these occur in diverse, adapted agronomic types and could be readily used in local breeding programs (Sharp and Reinhold, unpublished data).

Isolates from Sidney, MT, and Sakha, Egypt, showed an obvious lack of resistance when evaluated to the cultivars in Table 2. As described earlier, the isolate from Sidney differs considerably from virulence types described for other regions of the United States (6). The Sakha isolate originated in an area where severe outbreaks of the disease occur frequently. In 1979, only 27 among 7,000

entries in a U.S. Department of Agriculture nursery showed resistance or moderate resistance to *P. hordei* at Sakha, Egypt (Sharp, personal observation). Several sources of resistance to *P. hordei* described in this paper originated from these selections.

ACKNOWLEDGMENTS

We thank J. G. Moseman and D. H. Smith, Jr., Beltsville, MD; B. C. Clifford, Aberystwyth, Wales, U.K.; J. E. Parlevliet, Wageningen, the Netherlands; and L. Gallagher, Rabat, Morocco, for providing seed samples.

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