

# Virulence Types of *Puccinia hordei* from North America, North Africa, and the Middle East

M. REINHOLD, Postdoctoral Fellow, and E. L. SHARP, Professor of Plant Pathology, Department of Plant Pathology, Montana State University, Bozeman 59717

## ABSTRACT

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The virulence patterns of several *Puccinia hordei* (leaf rust) isolates originating in North America, North Africa, and the Middle East were determined by using a differential set of barley (*Hordeum vulgare*) cultivars representing the genes Pa-Pa<sub>9</sub>. Twelve different virulence types were found among the 14 isolates tested. The isolates collected in Montana were found to be more virulent than those collected in Texas and Minnesota. The isolate from Sakha (Egypt) appeared to have accumulated the highest number of virulence genes among the virulence types from North Africa. None of the isolates possessed virulence against the resistance genes Pa<sub>3</sub> in Estate and Pa<sub>7</sub> in Cebada Capa. CI 1243 carrying the gene Pa<sub>9</sub> was resistant to all isolates of *P. hordei* except for one isolate that originated from the alternate host (*Ornithogalum* spp.) near Tel Aviv, Israel. There was little similarity of reaction on cultivars reportedly carrying the Pa<sub>2</sub> gene or a complex of that gene, indicating that the Pa<sub>2</sub> complex involves more than one gene.

Additional key words: barley leaf rust

Leaf rust (*Puccinia hordei* Otth.) of barley (*Hordeum vulgare* L.) has been reported from all major barley-producing areas (8). The disease is considered as a yield-reducing factor in the southern and eastern United States, the Mediterranean basin, and recently in northwestern Europe. Estimated yield losses ranged as high as 80% on cultivars susceptible to *P. hordei* during a severe epidemic in Minnesota in 1935 (4). The fungus overwinters on barley in the southern United States and Mexico, where severe outbreaks of the disease are observed frequently. The urediniospores move with the prevailing winds across the central United States and into southern Canada. The alternate host, *Ornithogalum umbellatum* L., and other species are not considered to be of any importance for the disease cycle in the United States.

Races of *P. hordei* found in the United States, though differing considerably from each other, apparently all lack virulence to the resistance genes Pa<sub>3</sub> found in the barley cultivar Aim, Pa<sub>7</sub> found in Cebada Capa, Pa<sub>2</sub> found in Peruvian and Ariana, and Pa<sub>2</sub> + Pa<sub>5</sub> found in Quinn (5,6).

In the Mediterranean area, climatic

conditions are favorable for the development of leaf rust (1). Because the climate is very dry in the summer months, the fungus may be dependent on sexual reproduction on the alternate host to complete its life cycle. This should result in a higher frequency of new physiologic races. The only strain of *P. hordei* able to overcome the gene Pa<sub>7</sub> in barley has been found in Israel in the vicinity of the alternate host (3).

Leaf rust of barley has become a more significant disease in western Europe following improved control of *Erysiphe graminis* DC. f. sp. *hordei* Em. Marchal (powdery mildew) through use of cultivars resistant to the pathogen and chemical compounds (7). Although the virulence patterns of European isolates of *P. hordei* are quite different from those described from America, the gene Pa<sub>7</sub> in barley was effective against all isolates tested, and virulence to the gene Pa<sub>3</sub> has

been reported only from Great Britain and Germany (2,11).

In this study, virulence patterns of *P. hordei* on barley cultivars from the United States, North Africa, and the Middle East were determined and compared. The purpose of this study was to get a broad coverage of virulence types of *P. hordei* from widely separated geographic areas but not to perform an extensive survey on virulence per se.

## MATERIALS AND METHODS

The differential barley cultivars used represented the *P. hordei* resistance genes Pa-Pa<sub>9</sub>. Seed stocks were obtained either from Dr. D. H. Smith, Jr., U.S. Department of Agriculture (Small Grains Collection, Beltsville, MD 20705) or from the barley collection at Montana State University, Bozeman.

The isolates were collected from local barley cultivars and, in one case, from the alternate host in the Mediterranean area (Fig. 1). Collections from the United States originated from widely separated locations in Montana and Texas. The isolate from Minneapolis was obtained from Dr. R. Wilcoxson (University of Minnesota, St. Paul). Single-pustule cultures were increased on the barley cultivar Moore, CI 7251. The spores were vacuum-dried and stored at 4 C when freshly collected inoculum could not be used immediately (10). Eight to 10 seeds per differential cultivar were sown in 10-cm pots in sterilized Bozeman silt loam soil. The pots were then placed in a controlled-environment chamber with a 16-hr daily photoperiod (2.2-3.3 × 10<sup>4</sup> erg/cm<sup>2</sup> per second) at 15/24 ± 1 C

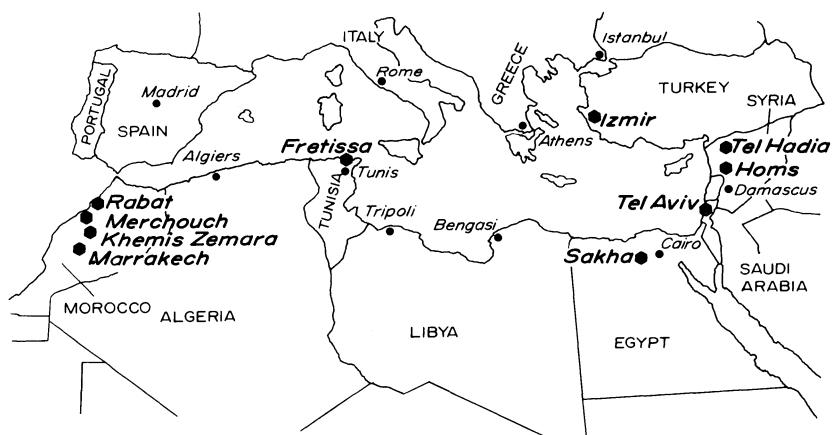


Fig. 1. Collection sites for *Puccinia hordei* in the Mediterranean area.

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(dark/light). Seedlings were inoculated when 9–10 days old with urediniospores suspended in distilled water. The inoculated seedlings were placed for 24 hr in a dew chamber at 20 C to allow spore germination and infection and were then returned to the growth chamber.

Disease readings were taken after 10 and 12 days. Five infection classes and three reaction types were recorded: 0 = no visible pustules (resistant); 1 = small pustules, infrequently with chlorosis and necrosis (resistant); 2 = definite chlorosis surrounding moderate-size pustules (intermediate); 3 = large pustules, some chlorosis (susceptible); and 4 = large pustules, no chlorosis (susceptible).

The intermediate reaction type was not considered to be significantly different from the resistant reaction for describing virulence types. Thus, cultivars expressing an intermediate reaction type are considered as sources of resistance to *P. hordei*.

## RESULTS

The isolates of *P. hordei* from near San Antonio, TX, and Minneapolis, MN, gave identical reactions on the differential cultivars (Table 1). Susceptible infection types 3 and 4 were observed only on the cultivars Reka I, Gold, and Egypt. Collections from the widely separated locations Creston and Sidney, MT, differed significantly in their virulence on Batna. The number of host differentials susceptible to the Montana isolates of *P. hordei* indicated an accumulation of

several virulence genes not present in collections from San Antonio or Minneapolis. The genes Pa<sub>2</sub> + Pa<sub>5</sub>, Pa<sub>3</sub>, Pa<sub>7</sub>, and Pa<sub>9</sub> represented in the cultivars Bolivia, Estate, Cebada Capa, and CI 1243, respectively, were effective against the three virulence types of *P. hordei* from North America (Table 1).

The North African isolates from Morocco, Tunisia, and Egypt represented significantly different virulence types (Fig. 1, Table 1). Collections from Merchouch, Khemis Zemara, and Marrakech showed similarities. The latter two can be considered as identical virulence types. The Merchouch, Morocco, isolate, however, was characterized by its virulence on Bolivia (Pa<sub>2</sub> + Pa<sub>6</sub>), and the generally ineffective gene Pa<sub>8</sub> in the cultivar Egypt conditioned an intermediate reaction type to this isolate. The Moroccan isolate from Rabat has more virulence genes than the three isolates described previously. A highly virulent isolate was obtained at Sakha, Egypt. However, the Pa<sub>2</sub>+ gene in Reka I conditioned high resistance to the Sakha isolate while being susceptible to all other isolates of the pathogen. The genes Pa<sub>3</sub>, Pa<sub>7</sub>, and Pa<sub>9</sub> were effective against all the isolates of *P. hordei* from North Africa. In addition, the cultivars Sudan (Pa) and Batna (Pa<sub>2</sub>+) were resistant or intermediate to all isolates of *P. hordei* from Morocco (Fig. 1, Table 1).

Isolates from the Middle East were collected in Israel, Syria, and Turkey (Fig. 1). The isolate from Tel Aviv was the

only isolate virulent on CI 1243 carrying the Pa<sub>9</sub> gene (Table 1). The most virulent isolate was found to occur in the dryland area near Homs, Syria. The collections from Tel Hadia, Syria, and Izmir, Turkey, were very similar and differed significantly only in reaction on Quinn (Pa<sub>2</sub>–Pa<sub>5</sub>). As already noted for the other areas, the genes Pa<sub>3</sub> and Pa<sub>7</sub> were effective against all isolates of *P. hordei* tested from the Middle East (Fig. 1, Table 1).

## DISCUSSION

Although the collection sites of the *P. hordei* isolates from Texas and Minnesota are separated by about 2,000 km, the cultures appeared to carry the same virulence genes. Because the fungus does not overwinter in Minnesota, it is likely that the spores move north with the prevailing winds. This movement is already known for *P. recondita* Rob. ex Desm. f. sp. *tritici* Eriks. & Henn. (leaf rust of wheat, *Triticum aestivum* L.) and *P. graminis* Pers. f. sp. *tritici* Eriks. & Henn. (stem rust of wheat), as well as for *P. coronata* Cda. var. *avenae* Fraser & Led. (crown rust of oats, *Avena sativa* L.). The virulence of the isolates from Texas and Minnesota was somewhat similar to the virulence pattern described for race 8 of *P. hordei*. However, race 8 was virulent on Sudan (Pa) and avirulent on Reka I (Pa<sub>2</sub>+), whereas the isolates from Minnesota and Texas were avirulent on Sudan but virulent on Reka I.

**Table 1.** Reaction of differential barley cultivars to isolates of *Puccinia hordei* from several locations<sup>a</sup>

Differential cultivars	(Host genes)	North America				North Africa				Middle East					
		Creston, MT	Sidney, MT	San Antonio, TX	Minneapolis, MN	Rabat, Morocco	Merchouch, Morocco	Khemis Zemara, Morocco	Marrakech, Morocco	Fretissa, Tunisia	Tel Hadia, Syria				
											Sakha, Egypt	Tel Aviv, Israel	Homs, Syria	Izmir, Turkey	
Sudan															
CI 6489	(Pa)	S	S	R	R	I	R	I	I	R	S	R	S	I	S
Peruvian															
CI 935	(Pa <sub>2</sub> )	S	S	R	I	S	R	R	I	I	S	I	I	S	I
Batna															
CI 3391	(Pa <sub>2</sub> +)	R	S	I	I	I	R	R	R	S	S	S	I	S	I
Reka I															
CI 5051	(Pa <sub>2</sub> +)	S	I	S	S	S	S	S	S	S	R	S	S	S	S
Ricardo															
CI 6306	(Pa <sub>2</sub> +)	S	S	I	R	S	R	R	R	I	S	I	I	S	I
Quinn															
CI 1024	(Pa <sub>2</sub> + Pa <sub>5</sub> )	S	S	R	R	S	I	S	S	I	S	R	S	S	I
Magnif															
CI 13806	(Pa <sub>5</sub> )	S	S	I	I	S	I	... <sup>b</sup>	I	S	S	R	S	S	S
Bolivia															
CI 1257	(Pa <sub>2</sub> + Pa <sub>6</sub> )	I	I	I	I	I	S	R	R	I	I	I	S	I	S
Estate															
CI 3410	(Pa <sub>3</sub> )	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Gold															
CI 1145	(Pa <sub>4</sub> )	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Cebada Capa															
CI 6193	(Pa <sub>7</sub> )	R	R	R	R	R	R	R	R	R	R	R	R	R	R
Egypt															
CI 6481	(Pa <sub>8</sub> )	S	S	S	S	S	I	S	S	S	S	S	S	S	S
CI 1243	(Pa <sub>9</sub> )	R	I	I	I	I	I	I	I	R	I	S	I	I	R

<sup>a</sup>S = susceptible, I = intermediate, and R = resistant to *P. hordei*.

<sup>b</sup>Seed not available at time of experiment.

The isolate from Texas originated in an area where severe leaf rust of barley occurs annually, but it had not accumulated many genes for virulence. This may agree with the hypothesis of Vanderplank (12) that races with unnecessary genes for virulence occur less abundantly because of decreasing fitness. On the other hand, the Montana isolates contained many genes for virulence even in the absence of a concerted program to develop cultivars resistant to *P. hordei*. Only a few genes for resistance to *P. hordei* have been used so far in the development of North American barley cultivars. There has thus been little selection pressure on the fungus to accumulate a high number of virulence genes.

The two isolates from Montana represent completely different virulence types. Both isolates were virulent on the genes Pa<sub>2</sub> in Peruvian and Pa<sub>2</sub> + Pa<sub>5</sub> in Quinn. These genes were reported earlier to be effective against isolates of *P. hordei* from different locations in North America (5,6).

The three Moroccan isolates of *P. hordei* were from dry locations (Merchouch, Khemis Zemara, and Marrakech) and appeared to be similar, whereas the isolate from the more humid coastal area of Rabat represents a completely different virulence type. The Khemis Zemara and Marrakech isolates can be considered as identical virulence

types because the differential cultivars and some 140 barley cultivars tested in this laboratory reacted the same with both isolates. The most virulent type of *P. hordei* in North Africa was found at Sakha, Egypt, where severe outbreaks of the disease occur regularly. In 1979, only 27 of 7,000 entries expressed some resistance to *P. hordei* at this location (E. L. Sharp, *unpublished*). The virulence patterns of the Sakha isolate and the Montana isolate from Sidney are similar on the differential cultivars. However, when considering a large number of barley cultivars, the virulence patterns differ substantially (9). The isolate from Tel Aviv, Israel, originated from the alternate host, *Ornithogalum* sp. The alternate host is known to be important for the development of new physiologic races (3), and in these studies the Tel Aviv isolate was the only one virulent on the gene Pa<sub>9</sub> in CI 1243 barley.

The Pa<sub>2</sub> gene found in the barley cultivar Peruvian and the Pa<sub>2</sub> complex in Batna, Reka I, Ricardo, Quinn, and Bolivia need further differentiation. Our results indicate that cultivars supposedly containing the Pa<sub>2</sub> gene differ significantly in their reactions and may, therefore, have different resistance genes to *P. hordei*.

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