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Resistance of barley landraces and wild barley populations to powdery mildew in Jordan

Adel H. ABDEL-GHANI[1], Nofal S. AL-AMEIRI[2] and Muwaffaq R. KARAJEH[2]

[1] Laboratory of Plant Breeding and Genetics, Department of Plant Production and
[2] Laboratory of Plant Pathology, Department of Plant Protection and IPM,
Faculty of Agriculture, Mutah University, P.O. Box 7, Karak 61710, Jordan

Summary. Eleven barley (*Hordeum vulgare* L.) landraces and 12 wild barley (*H. spontaneum*) populations, collected from diverse eco-geographical regions of Jordan, were screened for resistance to powdery mildew. The average powdery mildew disease score (based on a 0 to 4 severity scale) was <1 in all tested barley landraces. Disease scores in wild barley populations ranged from 1.2 to 3.8. Most barley landraces of all tested lines were highly resistant to powdery mildew. The percentage of wild barley lines exhibiting high resistance was 19%, while 45% of the lines were moderately resistant and 36% susceptible to powdery mildew. There was no significant correlation between weather variables (precipitation, temperature and altitude) and the disease scores of either the barley landraces or the wild barley populations. However, resistance in wild barley was more common in humid districts and at higher altitudes. Both barley landrace and wild barley accessions could serve as potential donors for powdery mildew resistance genes to be transferred to barley varieties improved by plant breeding.

Key words: *Blumeria graminis*, foliar disease, plant breeding.

Introduction

Barley (*Hordeum vulgare* L.) is the most widely cultivated field crop in Jordan, representing 37% of the total area planted with field crops (Anonymous, 2005). In the Mediterranean region, barley is grown predominantly in marginal agricultural areas (Ceccarelli, 1987; Abdel-Ghani *et al*. 2005). Landraces remain the major source of seeds for planting in most of the traditional barley growing areas, where barley is the only possible rainfed crop (Ceccarelli and Grando, 1999; Ceccarelli *et al*. 2000). Wild barley (*H. spontaneum* C. Koch) is recognized as the progenitor of cultivated barley (*H. vulgare*). The original area of cultivation of *H. vulgare* was probably the Fertile Crescent, the crescent-shaped region of rich farmland that in ancient times stretched from the Mediterranean Sea to the Arabian Gulf through the Tigris and Euphrates Valleys, including part of present-day Jordan (Harlan, 1995; Nesbitt, 1995; Willcox, 1995; Ladizinski, 1998).

Powdery mildew is one of the most destructive foliar diseases of barley (Rasmusson, 1985; Jorgensen, 1994). The disease is caused by the obligate biotrophic fungus *Blumeria graminis* (DC f. sp. *hordei*) Golovin ex Speer (*Bgh;* formerly known as *Erysiphe graminis* DC. f. sp. *hordei* Em Marchal) and is of great economic importance in many of the major barley-production regions (Ceccarelli *et al*., 1995). Powdery mildew occurs almost wherever barley is grown (Jorgensen, 1994). Epidemics develop under humid rainfed conditions and in dryland areas when irrigation is used to grow improved high-yield cultivars (Lyngkjaer and Ostergard, 1998). Powdery

Corresponding author: M.R. Karajeh
Fax: +962 03 2323154
E-mail: muwaffaq@mutah.edu.jo

mildew has become more important in some regions because of the increasing use of nitrogen fertilizers (Ceccarelli *et al.*, 1995; Rasmusson, 1985). *Bgh* infects all green plant parts, causing premature tissue senescence and severely curtailing yield (Lyngkjaer and Ostergard, 1998).

Powdery mildew on barley is genetically one of the best characterized systems of host–pathogen interactions. Geneticists, plant pathologists and breeders working with barley are constantly looking for gene pools from which new resistance genes to powdery mildew can be taken and introduced into existing barley cultivars (Czembor and Johnston, 1999; Czembor and Czembor, 2000).

Local primitive landraces of barley and wild barley populations are of great importance to broaden the narrow genetic base of new agricultural cultivars (Abdel-Ghani *et al.*, 2004). In 1926, Vavilov theorized that the Mediterranean region was one of the major centers where crops originated. He based this belief on the high diversity of crops, including barley, in this part of the world (Perrino, 1988). It is therefore possible that in this region barley has co-evolved with the fungus *Bgh* for a very long time. In the Mediterranean region, farmers still rely on landraces because powdery mildew and other diseases rarely develop on them to levels that significantly reduce yield. This lack of a yield loss in the landraces probably results from the presence of many resistance genes in mixtures of different genotypes (Czembor, 1976; Negassa, 1985; Ibrahim *et al.*, 1989). As a result, barley landraces and wild barley populations collected from Jordan may be a useful source of new genes resistant to powdery mildew. The objective of this study was to screen Jordanian barley landraces and wild barley populations for resistance to powdery mildew, and to correlate them with some eco-geographical characteristics of the collection sites.

Materials and methods

Plant material

In March 2004, field trips were undertaken to locate wild barley populations growing in the vicinity (2 to 3 km) of cultivated barley landraces grown on farms, where farmers preserve their own seeds for decades. A total of 11 barley landraces and 12 populations of wild barley were collected across the range of the species distribution in Jordan during May 2004 (Fig. 1 and Table 1). At each collection site, 15 lines per landrace or population were sampled by collecting one individual mature spike per plant at intervals of 1.0 to 1.5 m along the transects. A total of 345 spikes were collected. All collected barley landraces and wild barley populations had two-row heads and covered kernels. The geographical position of each site was mapped (Fig. 1). The altitude of the site was determined with a digital barometer-altimeter (model AIR-HB-1L, Sokkia Co. Ltd., Kanagawa, Japan). Long-term average seasonal rainfall and monthly temperature data were obtained from the Water Authority of Jordan and the Jordanian Weather Department.

Pathogen

Diseased plant samples with typical symptoms of powdery mildew were collected from wild barley plants grown in a field at the agricultural experimental station of the Faculty of Agriculture/Mu'tah University in Al-Rabbah, Karak province, Jordan. Slides were prepared by sampling the fungal mycelia that appeared on the surface of leaves showing chlorosis and necrotic lesions of powdery mildew. The fungus *Bgh* was identified as the causal agent of the powdery mildew through the morphological characteristics inspected under a compound microscope (Alexopoulos and Mims, 1979).

Pot experiment and disease assessment

A pot experiment was conducted in winter from mid-December 2004 to mid–April 2005 in a field at the agricultural experimental station Al-Rabbah. Five seeds per line were sown 2 cm deep in 25-cm-diameter pots filled with sterilized loam. Fifteen lines served as replicates for each landrace or population and all treatments were arranged in a randomized complete block design. The plants were regularly watered from the bottom of the pots. Local populations of *Bgh* were used for natural inoculation every year, since barley at the agricultural experimental station is always naturally infected with powdery mildew. Wild barley plants naturally heavily infected with powdery mildew grew commonly in or near the experimental area and very close to the tested plants; and these plants spread the pathogen throughout the experiment and were effective in ensuring uniform inoculum distribution to the test plants. Powdery mildew severity was scored just after heading and was continued until the end of the experiment. The 0–4 disease-score was as

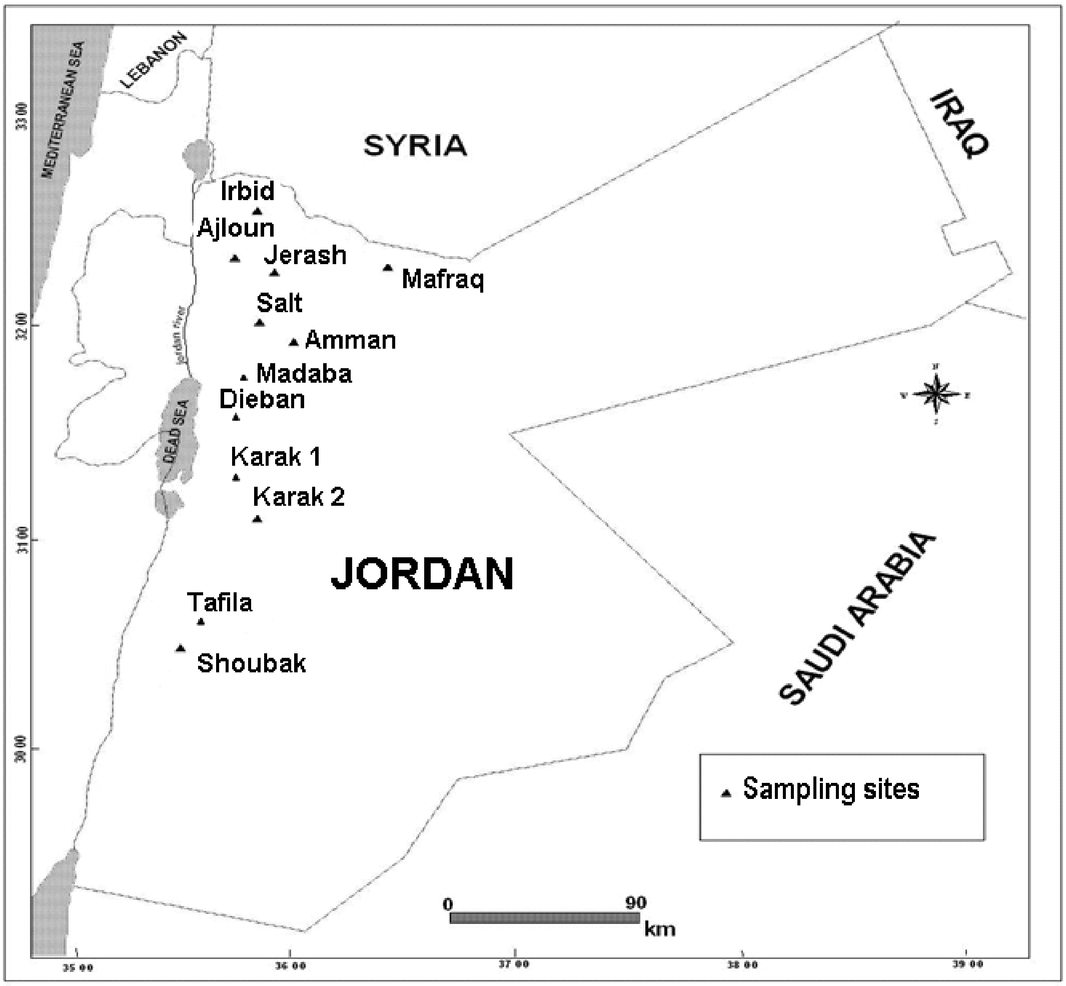

Fig. 1. Geographical distribution of cultivated barley (*Hordeum vulgare*) landraces and wild barley (*H. spontaneum*) populations in Jordan.

follows: 0, no visible symptoms; 1, minute necrotic flecks, no mycelial growth and no sporulation; 2, frequent chlorosis, reduced mycelial growth and no or very scarce sporulation; 3, moderate mycelial growth, moderate sporulation, and occasional chlorosis; 4, profuse sporulation of well-developed colonies (Mains and Dietz, 1930). Plants with disease scores of 0 to 1 were classified as highly resistant, plants that scored 2 and 3 as moderately resistant and plants with a score of 4 as susceptible (Negassa, 1987).

Data analysis

Data were analyzed with analysis of variance (ANOVA, SAS Institute Inc., Cary, NC, USA). The least significance difference (LSD) test was used to separate the means at P=0.05 (Steel and Torrie, 1980).

Results and discussion

Analysis of variance of disease severity revealed significant differences between populations (Table 2). Of the 165 lines of landraces, 157 lines (95%) were highly resistant to powdery mildew, and 8 lines (5%) moderately resistant, while no lines were susceptible. Of the 180 wild barley lines, 34 lines (19%) were resistant, 81 lines (45%) moderately resistant, and 65 (36%) susceptible (Table 3). All landrace lines from Jerash, Salt, Madaba, Dieban, Karak1 (Faqo), and Tafila districts were highly resi-

Table 1. Eco-geographical data for collection sites of the barley landraces and *Hordeum spontaneum* populations in Jordan.

District	Site	Latitude	Longitude	Average annual Rainfall (mm)	Altitude (m)	Average annual Temp. (°C)
Irbid	Sal	32° 39′	35° 49′	478	490	17.7
Mafraq	Manshia	32° 24′	36° 05′	152	850	16.5
Ajloun	Samta	32° 24′	35° 49′	547	1034	14.2
Jerash	Om Qntara	32° 17′	35° 56′	350	610	17.6
Salt	Yazidia	32° 05′	35° 46′	600	885	19.0
Amman	Sahab	31° 52′	35° 58′	275	878	17.3
Madaba	Team	31° 44′	35° 45′	358	785	16.6
Dieban	Baraza	31° 34′	35° 43′	270	715	16.0
Karak1	Faqo	31° 16′	35° 45′	326	890	16.2
Karak2	Mu'tah	31° 03′	35° 24′	350	1200	14.2
Tafila	Al Bada	30° 47′	35° 35′	250	1200	15.5
Shoubak	Ghair	30° 32′	35° 35′	315	1460	12.4

Table 2. Analysis of variance of disease severity rating data for 11 barley landraces and 12 wild barley populations.

Source of variation	Degrees of freedom	Sum squares	Mean squares	F value
Replication	14	5.792	0.414	1.57
Population	22	538.391	24.47	92.86 ***
Error	308	81.174		

***, Significant difference at 0.001 probability level.

stant, with no visible symptoms of powdery mildew on the plants. Some wild barley populations from these sites were also highly resistant (Table 3).

Resistance of the barley landraces and the wild barley populations to powdery mildew was not significantly correlated with the eco-geographical characteristics of the collection sites, including average annual rainfall, altitude and average annual temperature (data not shown). Although resistance in wild barley was common in humid environments (Irbid, Ajloun and Salt) and at higher altitudes (Tafila and Shoubak), yet several highly resistant lines were also found in Jerash, which has low rainfall (Table 1).

The study showed that barley landraces and some wild barley populations from the sampled districts (Irbid, Ajloun, Jerash, Tafila and Shoubak) in Jordan were potential sources of resistance to powdery mildew caused by *Bgh*. The study thus supported and supplemented van Leur *et al.* (1989), who found that some Jordanian barley landraces carried genes for resistance to powdery mildew.

The powdery mildew resistance observed in this study may have been specific to local *Bgh* populations. In previous studies, high levels of pathogenic variation were encountered in natural populations of *Bgh* (Limpert, 1987; Brown and Wolfe, 1990).

Barley plants resistant to powdery mildew were generally more frequent in areas of greater precipitation and at higher altitudes. Our data confirmed

Table 3. Reactions of barley landraces and wild barley to a local population of *Blumeria graminis* f. sp. *hordei*.

District	Barley landrace (*Hordeum vulgare*)					Wild barley (*Hordeum spontaneum*)				
	No. of lines	R[a]	M	S	Average DS[b]	No. of lines	R	M	S	Average DS
Irbid	15	13	2	0	0.83c ghd	15	4	11	0	1.93 d
Mafraq	15	14	1	0	0.33 ij	15	0	11	4	2.63 c
Ajloun	15	14	1	0	0.40 ij	15	3	12	0	1.83 d
Jerash	15	15	0	0	0.37 ij	15	10	5	0	1.20 fg
Salt	15	15	0	0	0.43 ij	15	5	10	0	1.43 ef
Amman	-	-	-	-	-	15	0	2	13	3.60 a
Madaba	15	15	0	0	0.13 j	15	0	1	14	3.80 a
Dieban	15	15	0	0	0.23 ij	15	0	2	13	3.67 a
Karak1	15	15	0	0	0.47 hij	15	0	9	6	3.10 b
Karak2	15	13	2	0	0.57 hi	15	0	0	15	3.73 a
Tafila	15	15	0	0	0.57 hi	15	8	7	0	1.20 fg
Shoubak	15	13	2	0	0.83 gh	15	4	11	0	1.67 de
Total	165	157	8	0		180	34	81	65	
%		95	5	0			19	45	36	

[a] R, highly resistant (rating of 0 or1); M, moderately resistant (rating of 2 or 3); S, susceptible (rating of 4) (Mains and Dietz, 1930).
[b] DS, disease score according to a disease severity rating scale from 0–4 (Mains and Dietz, 1930).
[c] Means of disease severity rating of 5 plants for 15 lines.
[d] Means followed by the same letter within the columns are not significantly different according to LSD ($P \leq 0.05$).

the findings of Fetch *et al*. (2003) that resistance to powdery mildew was more common in humid environments.

It is concluded that Jordanian barley landraces and some wild barley germplasm are potential sources of genes for powdery mildew resistance, which can be transferred to improved barley varieties by classical plant breeding techniques. Large-scale studies are needed to evaluate the barley landraces and the wild barley populations in additional sites and years, to identify specific genes for resistance to powdery mildew, and to characterize them in terms of their number and their action.

Literature cited

Abdel-Ghani A.H., H.K. Parzies, A. Omary and H.H. Geiger. 2004. Estimating the outcrossing rate of barley landraces and wild barley populations collected from ecologically different regions of Jordan. *Theoretical Applied Genetics* 109, 588–595.

Abdel-Ghani A.H., H.K. Parzies, S. Ceccarelli, S. Grando and H.H. Geiger. 2005. Estimation of quantitative genetic parameters for outcrossing-related traits in barley. *Crop Science* 45, 98–105.

Alexopoulos C.J. and C.W. Mims. 1979. *Introductory Mycology*. 3d edition, John Wiley and Sons, Inc., New York, NY, USA, 632 pp.

Anonymous, 2005. *Statistics*. Department of Statistics, Amman, Jordan, 24-33.

Brown J.K. and M.S. Wolfe, 1990. Structure and evolution of a population of *Erysiphe graminis* f. sp. *hordei*. *Plant Pathology* 39, 376–390.

Ceccarelli S., 1987. Tolerance to climatic stress. *Proceedings of the Fifth International Barley Genetics Symposium*, October 6–12, 1986, Okayama, Japan, 689—702.

Ceccarelli S. and S. Grando, 1999. Barley landraces from the Fertile Crescent: a lesson for plant breeders. Genes in the field. (S.B. Brush ed.), IPGRI–International, Development Research Center – Lewis Publishers, Rome, Italy, Ottawa, Canada and Boca Raton, FL, USA, 51–76.

Ceccarelli S., S. Grando and J.A. van Leur, 1995. Barley landraces of the Fertile Crescent offer new breeding options for stress environments. *Diversity* 11, 112–113.

Ceccarelli S., S. Grando, R. Tutwiler, J. Baha, A.M. Baha, A.M. Martini, H. Goodchild and M. Michael, 2000. A methodological study on participatory barley breeding. I. Selection phase. *Euphytica* 111, 91–104.

Czembor H.J., 1976. Sources of resistance of barley to *Erysiphe graminis* f. sp. *hordei*. *Hodowla Ro´sl. Aklim. Nasienn* 20, 467–490.

Czembor J.H. and H.J. Czembor, 2000. Powdery mildew resistance in selections from Moroccan barley landraces. *Phytoparasitica* 28(1), 65–78.

Czembor J.H. and M.R. Johnston, 1999. Resistance to powdery mildew in selections from Tunisian landraces of barley. *Plant Breeding* 118, 503–509.

Fetch T.G., B.J. Steffenson and E. Nevo, 2003. Diversity and sources of multiple disease resistance in *Hordeum spontaneum*. *Plant Disease* 87, 1439–1448.

Harlan J.R., 1995. Agricultural origins and crop domestication in the Mediterranean region. *Diversity* 11, 14–16.

Ibrahim I.F., A.A. Ali, E.M. Ghalib and A.H. Mahmoud, 1989. Resistance of some world barley collections to powdery mildew in Iraq. *Arab Journal of Plant Protection* 7, 16–22 (in Arabic).

Jorgensen J.H. 1994. Genetics of powdery mildew resistance in barley. *Critical Review of Plant Science* 13, 97–119.

Limpert E., 1987. Barley mildew in Europe: evidence of wind-dispersal of the pathogen and its implications for improved use of host resistance and of fungicides for mildew control. Integrated control of cereal mildews: Monitoring the pathogen. (M.S. Wolfe, E. Limpert and E. Martinus, ed.), Nijhoff, Dordrecht, The Netherlands, 31–33.

Ladizinski G., 1998. How many tough-rachis mutants gave rise to domesticated barley? *Genetic Resources and Crop Evolution* 45, 411–414.

Lyngkjaer M.F. and H. Ostergard, 1998. Interaction between powdery mildew and barley with *mlo5* mildew resistance. *Plant Pathology* 47, 252–258.

Mains E.B. and S.M. Dietz, 1930. Physiologic forms of barley mildew, *Erysiphe graminis hordei* Marchal. *Phytopathology* 20, 229–239.

Negassa M., 1985. Geographic distribution and genotypic diversity of resistance to powdery mildew of barley in Ethiopia. *Hereditas* 102, 113–121.

Negassa M., 1987. Possible new genes for resistance to powdery mildew, *Septoria* glume blotch and leaf rust of wheat. *Plant Breeding* 98, 37–46.

Nesbitt M., 1995. Clues to agricultural origins in the northern Fertile Crescent. *Diversity* 11, 142–143.

Perrino P., 1988. The diversity in Vavilov's Mediterranean gene center. *Kulturpflanze* 36, 85–105.

Rasmusson D.C., 1985. *Barley*. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America, Publishers, Madison, WI, USA, 522 pp.

Steel R. and J. Torrie, 1980. *Principles and Procedures of Statistics*. 2nd edition. McGraw-Hill Book Company, Inc., New York, NY, USA, 485 pp.

van Leur J.A., S. Ceccarelli and S. Grando, 1989. Diversity for disease resistance in barley landraces from Syria and Jordan. *Plant Breeding* 103, 324–335.

Vavilov N., 1926. *Origin and Geography of Cultivated Plants*. Cambridge University Press, Cambridge, UK, 22–135.

Willcox G., 1995. Archeobotanists sleuth out origins of agriculture from early Neolithic sites in the Eastern Mediterranean. *Diversity* 11, 141–142.

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