J. Agric. Sci. Technol. (2002) Vol. 4: 135-139

Inheritance of Resistance to Powdery Mildew (*Erysiphe graminis* f. sp. *hordei*) in Barley

M. R. Naghavi[1], M. R. Ghanadha[1] and B. Yazdi-Samadi[1]

ABSTRACT

Two barley *(Hordeun vulgare* L.) genotypes, Radical and Cwb, with good to moderate levels of resistance to powdery mildew were crossed with a highly susceptible cultivar (Afzal) to determine the genetics of resistance. The parents, Fl, F2 and F3 generations of each of the two crosses, were evaluated for powdery mildew resistance in the glasshouse and field at the College of Agriculture in Karaj during 2000. The x^2 analysis of the segregating ratios in the F3 generations indicated that the resistance was controlled by one gene at seedling stage and by two or three genes at adult plant stage in Cwb and Radical, respectively. Radical showed a higher level of resistance than the Cwb, therefore, it is a better source of resistance to powdery mildew.

Keywords: Barley, Genetics, Inheritance, Powdery mildew, Resistance,

INTRODUCTION

Powdery mildew caused by *Etysiphe graminis* f. sp. *hordei* is one of the most important diseases in barley particularly in northern parts of Iran. Based on the gene-for-gene hypothesis of Flohr (1955), which was confirmed for powdery mildew of barley by Moseman (1959), many race-specific powdery mildew resistance genes from different origions have been recognized in barley (Moseman, 1959; Wiberg, 1974; Gorge *et al*., 1993; Giese *et al*, 1993; Jorgensen 1994; Schonfeld *et al*., 1996), but most of them have already been overcome by new virulent strains (Jahoor and Fischbeck, 1993). The most economical and environmentally safe method for controlling powdery mildew is by growing resistant cultivars. Resistant lines have infection types varying from complete to moderate resistance depending on which mildew culture is inoculated, indicating that the resistance genes involved has a race-specific character (Jensen *et al*., 1982; Mastebrock *et al*., 1995). Most studies reported that resistance is controlled by one or two domnant genes, depending on mildew culture (Jensen *et al*., 1982; Jahoor and Fischbeck 1993). It is, therefore, important to collect more information on the genetics of resistance to this disease particularly using diverse gemiplasm. The present study was performed to determine the mode of inheritance of resistance to powdery mildew in two barley genotypes

MATERIAL AND METHODS

Two barley genotypes Radical and Cwb from Russia and England, respectively, were selected for their resistance to powdery mildew over several years and locations in the Seed and Plant Improvement Institute at Karaj, along with a susceptible cultivar from Iran, Afzal, which is very tolerant to salinity and drought stresses.

In order to test the mode of inheritance, two resistant genotypes were crossed to the susceptible cultivar and the F2 and F3 generations were produced for each cross. The

[1] Plant Breeding Department , Faculty of Agriculture, University of Tehran, Karaj, Islamic Republic of Iran.

[DOR: 20.1001.1.16807073.2002.4.3.7.1]

Fl plants were harvested in bulk and their seeds were space planted in the College of Agricultural Experimental Station at Karaj during the 1999 season to produce F2 seeds. The F3 lines were obtained by harvesting approximately 90 single plants from each F2 population. This research was done in two separate experiments and each experiment was planted with five generations namely P1, P2, Fl, P2 and F3 in glasshouse and field.

Experiment I

The P1, P2, Fl, F2 and F3 generations of each cross were grown in a glasshouse and the seedlings were inoculated with conidiospores of a mildew culture, named Gorgan, by shaking sporulating plants above them when the first leaf was fully expanded. The powdery mildew employed isolate originated from a single spore culture and showes avirulence to Mla8, M1a6, M1al4, Mlp and mlo5 but virulence to M1a7, Mla9,Mlal0, Mlk and Mlg resistance genes. During the periods of incubation a temperature of 18-20^{o}C was maintained. Ten days after inoculation, each primary leaf was evaluated for its mildew reaction using the 0-9 scale of Mastebroek *et al*. (1995), where 0 and 9 were completely resistant and fully susceptible respectively. Plants with an infection type (IT) of more than 6 were regarded as susceptible, while those with lower than 6 were considered resistant.

Experiment II

The five generations were planted in a randomized complete block design with three replications and each replication consisted of one row of P1, P2 and Fl, 10 rows of F2 and 30 rows of F3 generations. Field rows consisted of 1-metre rows seeded 15 cm apart with 50cm between rows. The powdery mildew epidemic was initiated by inoculating plants of Afzal, planted among each of the 10 rows at booting stage. The average disease severity was recorded according to a modified Cobb scale (Peterson *et al.*1948), when the susceptible cultivar had reached 90 to 100 % disease severity.

RESULTS AND DISCUSSION

The two resistant genotypes, Radical and Cwb, showed a powdery mildew infection type of 0 to 1 and 4 to 5, and a disease severity of 1 and 10, respectively. In contrast, there were infection types and a disease severity of 9 and 100, respectively, for the susceptible cultivar Afzal, (Table l).

The cross of Radical×Afzal, showed complete dominance resistance at seedling and adult plant stages, as the infection type and disease severity of the Fl plants were the same as resistant parent. The reaction of the

Table 1. Seedling infection type(IT) and disease severity assessment for barley genotypes and crosses(Fls) in glasshouse and field, respectively.

Genotype and Cross	Seedling IT[a]	Disease severity [b]
Radical	0 to l	1
Cwb	4 to 5	10
Afzal	9	100
RadicalxAfzal (Fl)	0 to 1	2
CwbxAfzal(F1)	7 to 8	10

[a] ITs are based on a 0 to 9 Mastebroek (1995) where: 0= no symptoms visible;l= distinct necrosis without visible mycelium; 4= distinct necrosis with moderate sporulation; 5=moderate necrosis with moderate sporulation;7=weak necrosis and/or moderate chlorosis with heavy sporulation; 8=weak chlorosis with heavy sporulation; and 9=no resistance reactions, abundant sporulation.

[b]Disease seventies are based on the modified Cobb scale(19).

[DOR: 20.1001.1.16807073.2002.4.3.7.1]

Table 2. The x^2 values for the segregation ratio of F3 lines from crosses between the susceptible genotype, Afzal, and the iwo resistant genotypes, Radical and Cwb, in glasshouse and field.

Cross	Number of F3 lines			Expecte ratio	X^2
	HR[a]	Seg[b]	HS[c]		
Glasshouse:					
Radical×Afzal	22	44	24	1:2:1	0.13^{ns}
Cwb×Afzal	19	48	23	1:2:1	0.48^{ns}
Field					
Radical×Afzal	83	5	2	59:4:1	0.081^{ns}
Cwb×Afzal	56	28	6	10:5:1	0.026^{ns}

[a] Homozygous resistant,
[b] Segregation for resistance
[c] Homozygous susceptible
ns: Not significant

Fl plants from Cwb×Afzal cross indicated moderate susceptibility at seedling stage, as the infection level was closer to the susceptible parent than to resistant one, whereas it showed moderate resistance at adult plant stage (Table 1).

The F3 data were used to estimate the number of loci controlling resistance, since it provided a better estimate than the F2 data. Tests of F3 plants at seedling stage for each cross showed a good fit of ratio 1 resistance: 2 segregating: 1 susceptible, indicating that resistance in both crosses was controlled by a single dominant gene. However, at adult stage and taking into consideation either homozygous or segregating as resistance (Singh *at al*., 1995), the F3 lines from Radical×Afzal fitted a 63:1 ratio and these of Cwb×Afzaj cross fitted a 15:1 ratio. These results indicated that resistance at adult plant stage in Radical was controlled by three dominant genes and in Cwb by two dominant genes. Thus, Radical should have a greater potential than Cwb in improving powdery mildew resistance in cultivated barley.

The results of this study are in agreement with the findings of Jensen *et al*.(1982); Jahoor and Fischbeck (1993); and Mastebroek and Balkema-boomstra (l995), for the number for resistance genes to powdery mildew in populations of wild barley *(Hordeum spontaneum)* from different origins. In a previous study, Schonfeld *et al.* (1996) reported a recessive and semi-dominant mode of inheritance in segregating F2 populations of barley lines derived from crosses with wild barley.

Jahoor and Fischbeck (1993) suggested increasing the efficiency in breeding for disease resistance by increasing different resistant genes in the same breeding cycle. However, the identification of the genes which are present in a new breeding line or cultivar is difficult using the traditional method based upon differentiation of reaction spectra according to Flor's gene-for-gene hypothesis (Jeger and Viljanen-Rollinson, 2001). This difficulty may be overcome if closely-linked molecular markers become available. In recent years, a number of gene loci for powdery mildew resistance in barley have been mapped using molecular markers (Schuller *et al*., 1992; Schonfed *et al.*, 1996; Buschges *et al*., 1997; Lahaye *et al.*, 1998; Schwarz *et al*., 1999; Wei *et al*., 1999; Kurth *et al.*, 2001).

The two resistance genotypes, Radical and Cwb, are suitable sources of powdery mildew resistance for localization of resistance genes at seedling and adult plant stages by molecular markers and can be used for the pyramiding of different resistance genes in future barley breeding.

[DOR: 20.1001.1.16807073.2002.4.3.7.1]

REFERENCES

1. Buschges, R., Hollricher, K., Panstruga, R., Simons, G., and Wolter, M.1997. The Barley *mlo* Gene: a Novel Control Element of Plant Pathogen Resistance. *Cell.*, **88**: 695-705.
2. Flohr, H. H. 1955. Host-parasite Interaction in Flax Rust-It Genetics and Other Implications. *Phytopathology.*, **45**: 680-685.
3. Giese, H., Holm-Jensen, A. G., Jensen, H. P., and Jensen, J. 1993. Localization of the Laevigatum powdery Mildew Resistance Gene to Barley Chromosome 2 by the Use of RFLP Markers. *Theor. Appl. Genet*., **85**: 897-900.
4. Gorge, R., Hollricher, K., and Schulze-Lefert, P. 1993. Functional Analysis and RFLP-Mediated Mapping of the *Mlg* Resistance Locus in Barley. *Plant J*., **3**: 857-866.
5. Jahoor, A. and Fischbeck, G. 1993. Identification of New Genes for Mildew Resistance of Barley at the Mla Locus in Lines Derived from *Hordeum spontaneum. Plant Breed.*, **110**: 116-122.
6. Jeger, M.J., and Viljanen-Rollinson, S. L. H. 2001. The use of the Area Under the Disease-progress Curve (AUDPC) to Assess Quantitative Disease Resistance in Crop Cultivars. *Theor. Appl. Genet.*, **102**: 32-40.
7. Jensen, H. P., Jorgensen, J. H., and Jensen, J. 1982. Attempts to Locate Powdery Mildew Resistance Gene *MI (La)* to a Barley Chromosome. *BGN.*, **12**: 65-68.
8. Jorgensen, J. H. 1994. Genetics of Powdery Mildew Resistance in Barley. *CRC Criti. Rev. Plant Sci.*, **13**: 97-119.
9. Kurtb, J., Kolsch, R., Simons, V., and Scbulze-Lefert, P. 2001. A Highresolution Genetic Map and a Diagnostic RFLP Marker for *Mlg* Resistance Locus to Powdery Mildew in Barley. *Theor. Appl. Genet.*, **102**: 53-60.
10. Lahaye, T., Hartmann, S., Topsch, S., Freialdenhoven, A., and Yano, M.1998. High-Resolution Genetic and Physical Mapping of the *Rarl* Locus in Barley. *Theor. Appl. Genet*., **97**: 526-534.
11. Mastebroek, H. D., and Balkemaboo-mstra, A. G. 1995. Genetic Analysis of Powdery Mildew Resistance Derived from Wild Barley. *Plant Breeding.*, **114**: 121-125.
12. Moseman, J. G. *1959.* Host-pathogen Interaction of the Genes for Resistance in *Hordeum Vulgare* and for Pathogenicity in *Erysiphe graminis* f. ssp. *hordei Phytopathology.*, **49**:469-472.
13. Peterson, R. F., Campbell, A. B., and Hannah, A. E. 1948. A. Diagrammatic Scale for Estimating Rust Intensity on Leaves and Stems of Cereal. *Can. J. Res.*, **26**: 496-500.
14. Schonfeld, M., Ragni, A., Fischbeck, G., and Jahoor, A. 1996. RFLP Mapping of Three New Loci for Resistance Genes to Powdery Mildew *(Etysiphe graminis* f. sp. *hordei)* in Barley. *Theor. Appl. genet.*, **93:** 48-56.
15. Schuller, C., Backcs, G., Fischbeck, G., and Jahoor, A. 1992. RFLP Markers to Identify the Alleles on the *Mla* Locus Conferring Powdery Mildew Resistance in Barley. *Theor. Appl. Genet*., **84**: 330-338.
16. Schwarz, G., Michalek, W., Mohler, V., Wenzel, G., and Jahoor, A. 1999. Chromosome Landing at the *Mla* Locus in Barley *(Hordeum vulgar* L.) by Means of High-resolution Mapping with AFLP Markers. *Theor. Appl. Genet*., **98**: 521- 530.
17. Singh, G., Rajaram, S., Montoya, J., and Fuentes-Davila, G. 1995. Genetic Analy-sis of Karnal Bunt Resistance in 14 Mexican Bread-wheat Genotypes. *Plant Breed.*, **114**:439-441.
18. Wei, F., Gobelman-Werner, K., Morroll, S. M., Kurth, J., Mao, L., Wing, R., and Leister, D. 1999. The *Mla* powdery Mildew Resistance Cluster is Associated with Three NBS-LRR Gene Families and Suppressed Recombination within a 240- kb DNA Interval on Chromosome 5S (1HS) of Barley. *Genetics*., **153**: 1929-1948.
19. Wiberg, A. 1974. Sources of Resistance to Powdery Mildew in Barley. *Hereditas.*, **78**: 1-40.

[DOR: 20.1001.1.16807073.2002.4.3.7.1]

توراث مقاومت به سفیدک سطحی در جو

م. ر. نقوی، م. ر. قنادها و ب. یزدی صمدی

چکیده

به منظور تعیین ژنتیک مقاومت به سفیدک سطحی در جو، دو ژنوتیپ مقاوم با یک واریته حساس (افضل) تلاقی داده شدند. واکنش والدین و نسلهای F3, F2, F1 حاصل از دو تلاقی نسبت به ایزوله سفیدک سطحی در شرایط گلخانه و مزرعه دانشکده کشاورزی کرج در سال ۱۳۷۹ مورد ارزیابی قرار گرفتند. تجزیه کای اسکور برای نسبتهای تفرق یافته در نسلF3 ی هر دو تلاقی مشخص نمود که مقاومت در مرحله گیاهچه با یک ژن کنترل می‌شود. در صورتیکه در مرحله گیاه بالغ، مقاومت در ژنوتیپ Cwb با دو ژن در ژنوتیپ Radical با سه ژن کنترل می‌گردد. از آنجایی که ژنوتیپ Radical علاوه بر داشتن ژنهای مقاوم بیشتر (در مرحله گیاه بالغ) دارای سطح مقاومت زیادتری نیز در مرحله گیاهچه می‌باشد، از این رو میتوان از آن به عنوان منبع بهتری از مقاومت به سفیدک سطحی در برنامه‌های اصلاحی در آینده استفاده نمود.

[DOR: 20.1001.1.16807073.2002.4.3.7.1]