Evaluation of *Aegilops* Species for Resistance to Wheat Powdery Mildew, Wheat Leaf Rust, Hessian Fly, and Greenbug

B. S. GILL, H. C. SHARMA, and W. J. RAUPP, Department of Plant Pathology, L. E. BROWDER, J. H. HATCHETT, USDA-ARS, and T. L. HARVEY, Fort Hays Branch, Kansas State University, Manhattan 66506; J. G. MOSEMAN, Plant Genetics and Germplasm Institute, USDA-ARS, Beltsville, MD 20705; and J. G. WAINES, Department of Botany and Plant Sciences, University of California, Riverside 92521

ABSTRACT

Gill, B. S., Sharma, H. C., Raupp, W. J., Browder, L. E., Hatchett, J. H., Harvey, T. L., Moseman, J. G., and Waines, J. G. 1985. Evaluation of *Aegilops* species for resistance to wheat powdery mildew, wheat leaf rust, Hessian fly, and greenbug. Plant Disease 69: 314-316.

Thirty-seven to 187 accessions of 16–21 *Aegilops* species were evaluated for resistance to powdery mildew (*Erysiphe graminis tritici*), leaf rust (*Puccinia recondita tritici*), Hessian fly (*Mayetiola destructor*), and greenbug (*Schizaphis graminum*). A high frequency of resistance to powdery mildew, leaf rust, and Hessian fly occurred among the *Aegilops* species. The frequency of resistance to greenbug was low and limited mainly to species containing the S-, D-, and C-genomes. Multiple resistance to two pathogens and two insects was identified in one accession each of *A. caudata, A. longissima, A. speltoides,* and *A. variabilis*, and to two pathogens and Hessian fly in six *Aegilops* species.

Pathogens and insects cause crop losses and instability in wheat yield. Breeding resistant cultivars is perhaps the most economical method of control. Genes for resistance are frequently overcome by new races of pathogens and insects, however, and different sources of resistance are needed to compete with the continuously evolving virulence of pest populations. Moreover, because breeding a crop impoverishes its genetic base, it is imperative that exotic gene pools be identified and incorporated into breeding programs.

The genus *Aegilops* is a useful source of alien genetic variation for disease resistance in wheat. There are 11 diploid, 9 tetraploid, and 4 hexaploid species of *Aegilops* distributed in southwestern Asia including Caucasus, northern Africa, and southern Europe (17). Because of their wide adaptation to diverse ecogeographic regions, *Aegilops* species were expected to be rich sources of genetic variation. Resistance to different pathogens has been identified in *Aegilops* species (1,12), and a recent literature review (15) cited several wheat cultivars with resistance genes from *Aegilops*.

The complete range of genetic variation that occurs in different *Aegilops* species is not known. Pasquini (12) evaluated the *Aegilops* species in the USDA world collection of small grains for resistance to leaf rust, stem rust, and powdery mildew. Our study was undertaken to evaluate previously untested accessions of *Aegilops* species in the University of California-Riverside (UCR) collection (excluding *A. squarrosa*) for resistance to powdery mildew, leaf rust, Hessian fly, and greenbug.

Cooperative investigations of Kansas Agricultural Experiment Station, California Agricultural Experiment Station, and USDA-ARS; Contribution 85-8-J, Department of Plant Pathology, Kansas Agricultural Experiment Station, Kansas State University, Manhattan. Research supported in part by grants from Kansas Wheat Commission, Kansas Crop Improvement Association, and Pioneer Hi-Bred Co.

Present address of second author: Monsanto Agricultural Products Co., 700 Chesterfield Village Parkway, Chesterfield, MO 63067.

Accepted for publication 26 September 1984.

MATERIALS AND METHODS

More than 300 accessions of *Aegilops* species are represented in the UCR collection. These accessions were increased at Kansas State University. Fifteen to 20 seeds were used in evaluating each accession for reactions to each pathogen and insect.

The accessions were evaluated for powdery mildew caused by *Erysiphe graminis* DC. ex Merat f. sp. *tritici* em Marchal by inoculating seedlings in separate plantings with one composite of cultures ABK and 127 and another of cultures Mo 10 and Quincy in greenhouse tests. The virulent/avirulent formulas (11) of the cultures are as follows: ABK = 1, 2, 6, 7/3a, 3b, 3c, 4, 5, 8, Ma, Amigo; 127 = 3b, 3c, 5/1, 2, 3a, 4, 6, 7, 8, Ma, Amigo; Mo 10 = 2, 3a, 3c, 5, 7, Ma, Amigo/1, 3b, 4, 6, 8; and Quincy = 2, 3a, 3c, 4, Ma/1, 3b, 5, 6, 7, 8, Amigo. The two composites possessed most of the virulence genes found in the United States. After inoculation, seedlings were maintained at 16–19 C with light for 12 hr/day. Reactions to infection were read 7–9 days after inoculation on a scale of 0–9, where 0 = immune, no visible signs of infection; 1–3 = highly resistant, increasing from no necrosis to large necrotic areas, increasing from no mycelium to little mycelium; 4–6 = intermediately resistant, necrotic areas changing to chlorotic areas, increasing in amounts of mycelium and conidiospore production; and 7–9 = susceptible, decreasing from chlorotic areas to no chlorosis, increasing in amount of mycelium and conidiospore production to complete susceptibility (11,16).

Seedlings were tested for reactions to *Puccinia recondita* Rob. ex Desm. f. sp. *tritici* culture PRTUS6 using the urediniospore-oil suspension inoculation method and plant growing method described by Browder (2). Culture PRTUS6 was selected because it was virulent to lines with several of the known *Lr* genes and many commercial cultivars grown in Kansas. PRTUS6 can be described with the avirulence/virulence formula 2a, 9, 16, 18, 19, 24/1, 2c, 2d, 3a, 10, 11, 17. Infection types were produced under growth chamber conditions at 20 ± 2 C and a 12-hr day at about 2,000 lux. Infection types were observed 10–12 days after inoculation and coded according to the system of Browder and Young (3). A line was considered resistant if associated with an infection type with a sporulation rating of 0, 1, or 2 on a scale of 0–9.

Accessions were evaluated in a greenhouse for resistance to biotype D of Hessian fly (*Mayetiola destructor* Say). Biotype D larvae infest wheats carrying *H*1, *H*2, *H*3, *h*4, *H*6, *H*7, and *H*8 genes but not wheats carrying *H*5 or *H*9. Greenhouse temperature was maintained at about 20 C throughout the test. Twenty seeds of each accession were seeded in a row in standard greenhouse flats containing soil (10 rows per flat). Methods of infestation and of determining resistance or susceptibility of individual seedlings were similar to those described by Cartwright and LaHue (4). Adult Hessian flies were allowed to oviposit on seedlings in the one-leaf stage for 2 days. Plants were then examined for eggs and infested with 10–15 eggs per plant. Plant reaction was determined about 15 days after infestation; individual plants were classified as resistant or susceptible. Susceptible plants were stunted and dark green. Resistant plants were not stunted; they were yellowish green and showed a high level of antibiosis in that all larvae died in the first instar. Resistant and susceptible plants were also examined for dead or live larvae; live larvae were found only on susceptible plants.

Greenbug (*Schizaphis graminum* Rond.) biotype E, the predominant biotype in the Midwest, attacks both wheat and sorghum. Amigo wheat, which was resistant to biotype C, is susceptible to biotype E. For the greenbug resistance test, 10 apterous adult biotype E greenbugs were placed on each plant at the two- to three-leaf stage, and the plants were enclosed in plastic cages in a greenhouse maintained at about 22 C. Resistance was determined 8–10 days later. Susceptible plants began to show generalized chlorosis after 5–7 days and were easily distinguished from the dark green resistant plants. Resistance involves tolerance as well as antibiosis and/or nonpreference (8).

RESULTS

A variable number of accessions, depending on seed germination and availability, from 10 diploid and 11 polyploid species of *Aegilops* were tested for resistance or susceptibility to powdery mildew, leaf rust, Hessian fly, and greenbug. There was high frequency of resistance to powdery mildew, leaf rust, and Hessian fly but low frequency of resistance to greenbug (Tables 1 and 2).

Thirty-seven accessions from 16 *Aegilops* species were evaluated for reactions to powdery mildew; 30 gave highly resistant to intermediate and seven gave susceptible reactions (Tables 1 and 2). One hundred eighty-seven accessions from 21 species were evaluated for leaf rust reactions; 124 were resistant and 63 were susceptible. One accession of *A. umbellulata* segregated for resistant and susceptible plants. Eighty accessions from 18 species were evaluated for reactions to Hessian fly; 48 were resistant or segregating for resistant and susceptible plants and 32 were susceptible. Fifty-three accessions from 17 *Aegilops* species were evaluated for reactions to greenbug; 10 were resistant and 43 were susceptible.

Multiple resistance, as determined from reactions to separate inoculations/infestations, was found among accessions of some species. Accessions with multiple resistance to three or more pathogens and insects are listed in Table 3 by species name, genomic symbol, and country of origin. Not all accessions of some species were tested for reactions to two pathogens and two insects; therefore, multiple resistance could not be evaluated in those species (Tables 1 and 2). One accession each of *A. caudata* (Manhattan accession 1905), *A. longissima* (1924), *A. speltoides* (1783), and *A. variabilis* (1889) was resistant or segregating for resistance to all four pathogens and insects. One accession each of *A. sharonensis* (2065) and *A. variabilis* (1898) was susceptible only to leaf rust. The remaining accessions, from *A. umbellulata, A. triaristata, A. triuncialis, A. comosa*, and *A. ovata*, were resistant to powdery mildew, leaf rust, and Hessian fly but were susceptible to greenbug.

DISCUSSION

This survey shows that *Aegilops*

Table 1. Evaluation of accessions of diploid species of *Aegilops* for resistance to powdery mildew, leaf rust, Hessian fly, and greenbug[a]

	Powdery mildew		Leaf rust		Hessian fly		Greenbug	
Species and genome	R	S	R	S	R	S	R	S
A. speltoides (S)[b]	1[c]	0	16	1	12 (6H)	11	1	2
A. longissima (S^{p})	2	0	2	2	3 (2H)	3	1 (H)	1
A. sharonensis (S^{sh})	2	0	1 (H)	3	1 (H)	1	2 (1H)	0
A. bicornis (S^{b})	4 (2I)	0	1	8	2 (H)	3	0	7
A. caudata (C)	1	1	1	1	1 (H)	1	1	0
A. umbellulata (U)	6 (3I)	0	10 (1H)	1	5 (H)	1	1 (I)	6
A. comosa (M)	2 (1I)	1	3	2	1 (H)	2	0	3
A. uniaristata (Un)	···	···	0	2	···	···	···	···
A. mutica (Mt)	···	···	0	1	0	1	···	···
A. searsii (S)	···	···	2	1	···	···	···	···
Total accessions	18	2	36	22	25	23	6	19

[a] R = resistant, I = intermediate resistant, S = susceptible, and H = segregating R and S.
[b] Species genome symbols from Kimber (10).
[c] Number of accessions with indicated disease reaction.

Table 2. Evaluation of accessions of polyploid species of *Aegilops* for resistance to powdery mildew, leaf rust, Hessian fly, and greenbug[a]

	Powdery mildew		Leaf rust		Hessian fly		Greenbug	
Species and genome	R	S	R	S	R	S	R	S
A. triuncialis (UC)[b]	2[c]	1	42	7	4 (2H)	3	0	8
A. triaristata (UM or UMun)	1	0	9	0	2 (H)	1	0	2
A. columnaris (UM)	2	0	2	1	1 (H)	1	0	2
A. ovata (UM)	3	0	15	2	4 (2H)	0	0	4
A. biuncialis (UM^{b})	1	0	2	3	0	2	0	2
A. variabilis (US^{v})	2	0	8	1	2 (H)	1	2	1
A. kotschyi (US^{1})	···	···	0	3	0	1	0	1
A. cylindrica (CD)	0	1	10	1	4	0	0	4
A. ventricosa (DUn)	0	3	0	4	3	0	0	3
A. crassa (DM or DDM)	1	0	0	15	3 (2H)	0	2 (1H)	0
A. juvenalis (DMU)	···	···	0	4	···	···	···	···
Total accessions	12	5	88	41	23	9	4	27

[a] R = resistant, H = segregating, and S = susceptible.
[b] Species genome symbols from Kimber (10).
[c] Number of accessions with indicated disease reaction.

Table 3. Multiple resistance in accessions of diploid and polyploid species of *Aegilops*[a]

Species and genome	Manhattan and UCR[b] accession no.	Country of origin	Powdery mildew	Leaf rust	Hessian fly	Greenbug
A. caudata (C)[c]	1905 (G 857)	Italy	R	R	H	R
A. comosa (M)	2102 (G 601)	Greece	R	R	H	S
A. longissima (S)	1924 (G 759)	?	R	R	H	R
A. speltoides (S)	1783 (G 617)	Israel	R	R	H	R
A. umbellulata (U)	1825 (G 1149)	Turkey	R	H	H	S
A. sharonensis (S^{sh})	2065 (G 615)	Turkey	R	S	H	R
A. triaristata (UM)	1868 (G 951)	?	R	R	H	S
A. triuncialis (UC)	1719 (G 392)	Turkey	R	R	R	S
A. ovata (UM)	1711 (G 422)	Turkey	R	R	R	S
	1813 (G 860)	Italy	R	R	H	S
	1814 (G 767)	Romania	R	R	H	S
A. variabilis (US)	1889 (G 1311)	Israel	R	R	H	R
	1898 (G 955)	?	R	S	H	R

[a] R = resistant, H = segregating, and S = susceptible.
[b] University of California-Riverside.
[c] Species genome symbols from Kimber (10).

species are a good source of disease and insect resistance. Pasquini (12) reported a high incidence of resistance to Italian races of leaf rust and powdery mildew among *Aegilops* species. This genus should be studied and exploited more for wheat improvement, since genomes B and D of common wheat (AABBDD) came from *Aegilops*. Some *Aegilops* accessions segregated for Hessian fly and leaf rust resistance factors. This heterogeneity could be attributed to either mechanical mixture or outcrossing in the original collection or during seed increase.

Most of the resistant accessions came from species with the S genome, which in turn is most closely related to the B genome of wheat. Greenbug resistance, rare in cultivated wheat (8), was most common in the S-genome diploid species and polyploid species containing the D genome. Thus, the *Aegilops* species with the S and D genomes will provide the most readily available source of disease and insect resistance (5,6,9).

The resistance from *Aegilops* species with basic genomes C, M, and U and other modified genomes will be more difficult to transfer into wheat. However, the expression of genes transferred from *Aegilops* to wheat is unaltered compared with reduced expression of genes transferred from progenitor *Triticum* species (7). Specialized cytogenetic techniques have been used successfully to make genetic transfers from *A. umbellulata* (14) and *A. comosa* (13). These techniques are undergoing constant improvement, and genetic transfers from all *Aegilops* species are now possible. Studies are under way on the transfer of genes for resistance from *Aegilops* into common wheat.

LITERATURE CITED

1. Bell, D. G., and Lupton, F. G. H. 1955. Investigation of the Triticinae. IV. Disease reactions of species of *Triticum* and *Aegilops* and amphiploids between them. Can. J. Genet. Cytol. 5:83-88.
2. Browder, L. E. 1971. Pathogen specialization in cereal rust fungi, especially *Puccinia recondita* f. sp. *tritici*: Concepts, methods of study and application. U.S. Dep. Agric. Tech. Bull. 1432. 51 pp.
3. Browder, L. E., and Young, H. C. 1975. Further development of an infection-type coding system for the cereal rusts. Plant Dis. Rep. 59:964-965.
4. Cartwright, W. B., and LaHue, D. W. 1944. Testing wheats in the greenhouse for Hessian fly resistance. J. Econ. Entomol. 37:385-387.
5. Doussinault, G., Delibes, A., Sanchez-Monge, R., and Garcia-Olmedo, F. 1983. Transfer of a dominant gene for resistance to eyespot disease from a wild grass to hexaploid wheat. Nature 303:698-700.
6. Dvorák, J. 1977. Transfer of leaf rust resistance from *Aegilops speltoides* to *Triticum aestivum*. Can. J. Genet. Cytol. 19:133-141.
7. Gill, B. S., Browder, L. E., Hatchet, J. H., Harvey, T. L., Martin, T. J., Raupp, W. J., Sharma, H. C., and Waines, J. G. 1984. Disease and insect resistance in wild wheats. Int. Wheat Genet. Symp., 6th. Kyoto, Japan.
8. Harvey, T. L., Martin, T. J., and Livers, R. W. 1980. Resistance to biotype C greenbug in synthetic hexaploid wheats derived from *Triticum tauschii*. J. Econ. Entomol. 73:387-389.
9. Kimber, G. 1967. Incorporation of the resistance of *Aegilops ventricosa* to *Cercosporella herpotrichoides* into *Triticum aestivum*. J. Agric. Sci. Cambridge 68:373-376.
10. Kimber, G. 1984. Assignment of genome symbols in the Triticeae. Int. Wheat Genet. Symp., 6th. Kyoto, Japan.
11. Moseman, J. G., Nevo, E., and Zohary, D. 1983. Resistance of *Hordeum spontaneum* collected in Israel to infection with *Erysiphe graminis hordei*. Crop Sci. 23:1115-1119.
12. Pasquini, M. 1980. Disease resistance in wheat. II. Behavior of *Aegilops* species with respect to *Puccinia recondita* f. sp. *tritici*, *Puccinia graminis* f. sp. *tritici*, and *Erysiphe graminis* f. sp. *tritici*. Genet. Agric. 34:133-148.
13. Riley, R., Chapman, V., and Johnson, R. 1968. Introduction of yellow rust resistance of *Aegilops comosa* into wheat by genetically induced homoelogous recombination. Nature 216:383-384.
14. Sears, E. R. 1956. The transfer of leaf rust resistance from *Aegilops umbellulata* to wheat. Brookhaven Symp. Biol. 9:1-22.
15. Sharma, H. C., and Gill, B. S. 1983. Current status of wide hybridization in wheat. Euphytica 32:17-31.
16. Tomerlin, J. R., El-Morshidy, M. A., Moseman, J. G., Baenziger, P. S., and Kimber, G. 1984. Resistance to *Erysiphe graminis* f. sp. *tritici*, *Puccina recondita* f. sp. *tritici*, and *Septoria nodorum* in wild *Triticum* species. Plant Dis. 68:10-13.
17. Waines, J. G., Hiln, K. W., and Sharma, H. C. 1982. Species formation in *Aegilops* and *Triticum*. Pages 88-108 in: Grasses and Grasslands: Systematics and Ecology. J. R. Estes, R. J. Tyrl, and J. M. Brunken, eds. University of Oklahoma Press, Norman.