Genetic Studies of Field Reaction to Wheat Soilborne Mosaic Virus

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ABSTRACT

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The inheritance of field reaction to wheat soilborne mosaic in winter wheat was studied in F_1, F_2, F_3, and F_4 generations from a seven-parent diallel cross. The resistant parents were Shawnee, Oasis, KS73148, and KS73256. Centurk was moderately resistant, Gage moderately susceptible, and Eagle susceptible. Resistance and susceptibility were controlled by a single locus, with resistance dominant over susceptibility. The resistant lines seemed to share the same factor for resistance despite different origins. Centurk was a mixture of resistant and susceptible genotypes. No segregation for resistance was observed in Gage × Eagle cross, but later in the season the Gage type recovered from infection better than the Eagle type.

Additional key words: disease resistance

Wheat soilborne mosaic (WSBM), one of the most destructive diseases of wheat (*Triticum aestivum* L.) in Kansas, is caused by a soilborne virus transmitted by the zoospores of *Polymyxa graminis* Led., which is associated with the roots of wheat and other grasses. McKinney (4) observed the disease in Illinois and described two phases, mosaic and mosaic-rosette, which are caused by the yellow and the green strains, respectively, of the virus. The first epiphytotic reported in Kansas was in 1952 (3). Only the yellow strain has been reported in Kansas. By 1969, WSBM had spread from eastern to south-central Kansas. In 1979, about 810,000 ha of wheat were infected, causing a loss of 167,000 tons. A 46% loss in yield was reported in Kansas (7).

Different cultural practices designed to control the disease have been inefficient or impractical. The use of resistant cultivars has proved to be the best control. McKinney (4) emphasized the importance of understanding the genetics of resistance to WSBM. Workers in Japan and the United States studied the inheritance of field reaction to WSBM and seemed to agree on a simple mode of inheritance of resistance. Miyake (5) suggested that resistance to both the yellow and the green strains was caused by a single dominant gene. Nakagawa et al (6) suggested that three loci with multiple alleles control resistance to WSBM. Shaalan et al (8) in Kansas reported that resistance to the yellow strain was controlled by two factors, a partially dominant gene and a modifying gene. Dubey et al (2) in Illinois concluded from the study of F_1, F_2, F_3, and backcross F_2 families from a five-parent incomplete diallel cross that resistance to both the yellow and the green strains was dominant over susceptibility and was controlled by a single gene. Such disagreements on the genetics of field reaction to WSBM can be attributed to differences in the environment as well as the cultivars used.

This paper reports results from our study of field reaction to WSBM in the progeny of a seven-parent complete diallel cross at different levels of field infestation in different locations in Kansas.

MATERIALS AND METHODS

In 1975, seven winter wheat cultivars with different field reactions to WSBM (Table 1) were intercrossed among themselves, giving 21 crosses (42 crosses including the reciprocals). Five to seven plants from each cultivar were selected at random as parents. The F_1's and the parents were seeded in naturally infested fields near Manhattan, KS, and their reactions were classified according to the leaf symptoms and growth habit as resistant (R) = no mottling on the leaves, plants not stunted; moderately resistant (MR) = very slight mottling, no stunting; moderately susceptible (MS) = mottling obvious, with some stunting; and susceptible (S) = severe mottling and stunting.

In fall 1977, the F_2 populations were space planted in 2.4-m rows in naturally infested soil near Manhattan and Hesston, KS. The parents of each cross were seeded in every 20th and 21st rows. The F_2 populations were classified as resistant, segregating, or susceptible. In 1978, about 25 randomly selected seeds from each F_2 plant were seeded as F_3 lines in 0.9-m rows together with the parents, as in the F_2 populations. F_3 and F_4 generation lines were studied again in 1979 and 1980.

In summer 1979, more than 200 heads were harvested at random from Gage, Centurk, and Rocky, and seed was planted in fall 1979 in 0.9-m rows in infested fields near Manhattan. Kansas resistant lines were crossed to resistant introductions from Europe and lines within the United States. Throughout the study, readings of field reactions to WSBM were taken in the spring after the wheat plant resumed growth. Most of the observations were made in early April and rechecked in middle or late April. The uniformity of field infestation was estimated by using the susceptible cultivar RedChief as standard.

RESULTS AND DISCUSSION

Centurk was generally classified as moderately resistant. During the first 2 yr of the study, we observed an irregular response to WSBM. In some crosses, reciprocal differences were observed in the F_1, but the F_2 segregation did not suggest the presence of cytoplasmically inherited factors. Random head selections from Centurk in 1979 showed that

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Table 1. Seven parental wheat lines and their field reaction to wheat soilborne mosaic in Kansas

Cultivar	CI or selection no.	Field reaction to WSBM
Shawnee	CI 14157	Resistant
Oasis	CI 15929	Resistant
CIMMYT/Scout	KS 73148	Resistant
CIMMYT/Scout	KS 73256	Resistant
Centurk	CI 15075	Moderately resistant
Gage	CI 13532	Moderately susceptible
Eagle	CI 15068	Susceptible

Table 2. Field reaction[a] of individual spike progeny of Centurk, Rocky, and Gage to wheat soilborne mosaic in 1980

Cultivar	R	GMR	MR	S	Total no. of lines
Centurk	19	48	15	136	218
Rocky	39	170	3	0	212
Gage	0	0	0	226	226

[a] R = all plants in the row resistant, GMR = a few plants infected but most resistant, MR = all plants with mild infection, and S = all plants severely infected.

Table 3. Field reaction to wheat soilborne mosaic in F_1 and F_3 lines from crosses of resistant × susceptible cultivars

Cross (year tested)	F_1	F_3 R[a]	F_3 S	χ^2	P[b]
Shawnee × Gage (1979)	R	103 (94.5)[c]	23 (31.5)	3.05	0.10–0.05
Shawnee × Gage (1980)	...	81 (88)	36 (29)	2.07	0.25–0.10
Shawnee × Eagle (1979)	R	95 (91.5)	26 (30.5)	0.53	0.50–0.25
Oasis × Eagle (1979)	R	102 (94.5)	24 (31.5)	2.37	0.25–0.10
KS73148 × Gage (1979)	R	132 (112)	18 (38)	13.80	0.005
KS73148 × Eagle (1979)	R	76 (100)	58 (34)	21.70	0.005
Oasis × Gage (1979)	R	137 (113)	14 (38)	20.20	0.005

[a] R = Resistant + segregating lines; S = susceptible lines.
[b] Probability of a greater χ^2 value.
[c] Figures in parentheses are expected frequencies in each class considering one-gene segregation (3:1).

Centurk was a mixture of resistant and susceptible genotypes (Table 2). Gage was found to be homogenously susceptible to WSBM. Some of the crosses involving KS73256 also showed reciprocal differences in the F_1, but the possibility of cytoplasmic inheritance was excluded because of the segregation in the F_2 and F_3 generations. Accordingly, crosses involving Centurk or KS73256 are not reported.

Crosses of the resistant × resistant cultivars gave all resistant progeny. Because all the F_3 lines were resistant, it was concluded that the cultivars Shawnee, Oasis, and KS73148 shared at least one gene homozygous for resistance to WSBM.

Eagle and Gage were susceptible to WSBM. Gage was susceptible in early spring, but as temperatures increased symptoms became less visible on Gage than on Eagle. Campbell et al (1) reported that Gage recovered better than Eagle and gave higher yields. The study of 110 F_3 lines in 1979 and 1980 showed that all the progeny of the Gage × Eagle cross in F_3 and F_4 generations were susceptible, indicating that neither cultivar carried any gene conditioning resistance to WSBM. However, some segregation was observed for the Eagle-type and Gage-type of response to recovery.

Crosses of the resistant × susceptible cultivars all gave resistant F_1 plants, indicating that resistance to WSBM was dominant over susceptibility. Table 3 shows the reaction of the F_3 lines from these crosses. The response to WSBM was placed in two classes. The resistant class included both the resistant lines and the segregating lines because of the difficulty in separating the resistant lines from the segregating lines under varying field infestations; the susceptible class included lines in which all plants were susceptible. In the 1980 field study, symptoms were more distinct than in 1979. This was reflected in the difference between the number of susceptible lines in the progeny of Gage × Shawnee. In both years, however, a close fit to a 3 resistant:1 susceptible ratio suggested a single gene difference between the two cultivars.

The F_3 lines from the crosses of Shawnee × Eagle and Oasis × Eagle segregated in a 3:1 ratio, suggesting that both resistant cultivars had a single dominant gene conditioning resistance to WSBM. Crosses of Gage × Oasis and Gage × KS73148 had more resistant lines than would be expected from a single gene segregation. Other hypotheses as reported in Japan (6) and Kansas (8) may explain the genetics of these crosses, but we believe that the excess of resistant lines resulted from a lack of uniformity of field infestation. The susceptible cultivar RedChief used as a border showed clear WSBM symptoms of severe mottling and stunting, indicating good field infestation; however, there were plants with lower levels of infection in spots around the field, a feature very characteristic of WSBMV field infestation.

The study of the head-row progeny of Centurk showed that this cultivar was a mixture of resistant and susceptible genotypes (Table 2). Head-row progeny of Rocky, a selection from Centurk, were homogenous for response to WSBM, with slight symptoms showing under heavy infection. Head-row progeny of Gage indicated that it was homogenous for response to WSBM but showed rapid recovery when temperatures increased.

From our study during several seasons and locations, we concluded that a single major gene controls the expression of resistance to WSBM in Kansas. However, the expression of resistance is greatly influenced by the environment and the genetic background of the cultivar, which determines its ability to repair, regrow, and recover from infection. Such tolerance may explain the differences between Gage and Eagle.

Most of the resistance used in the Kansas breeding program traces back to Turkey. About 30% of the Turkey CI1558 plants are resistant to WSBM. Comanche is an example of a resistant selection involving Turkey. Newton is resistant to WSBM, and its resistance could come from Argentina via Klein Rendidor. Plainsman V, origin unknown, also resists WSBM. These cultivars crossed among themselves and with Samson, David, Odesskaya 51, Pantizanka, and Priboy, cultivars from Europe showing resistance, gave all resistant progeny. Newton crossed with U.S. soft wheats such as Arthur 71 and hard wheats such as Homestead gave all resistant progeny. Although the symptoms among these resistant cultivars vary, no susceptible segregates occur from crosses involving these cultivars. This suggests that all the sources of resistance to WSBM that we are using in our breeding program may be the same.

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