Fusarium Head Blight Resistance in Spring Wheat Cultivars

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ABSTRACT

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Fusarium head blight (FHB), also called scab, caused by *Fusarium graminearum* was generally more severe in spring wheat cultivar Wheaton than in cv. Marshall, except in years when weather was excessively dry or wet during flowering and kernel-fill stages of plant growth. Fifteen wheat cultivars from the upper midwestern United States were evaluated in 1988, 1989, and 1990 for FHB resistance. FHB index (the percentage of spikelets infected in 50 spikes) was least in cv. Stoa each year. The FHB index varied with the other cultivars, but Wheaton was among the most severely infected, and Marshall was among the intermediate cultivars. The FHB index value was greatest in 1989 when rain favored disease development, least in 1988 when drought was severe, and intermediate in 1990. FHB incidence and severity did not differentiate cultivars as well as index values did. The FHB reactions of Chinese cultivars Fan 1 and Su Mai 3 were similar to those of Minnesota cultivar Marshall. Reactions of other Chinese cultivars were similar to those of susceptible Wheaton.

Fusarium head blight (FHB), also called scab, of wheat (*Triticum aestivum* L.) is an important disease throughout much of the world's wheat-growing areas especially when warm moist conditions coincide with flowering and kernel-fill stages of plant growth (3,8,10,11,15). In Minnesota, FHB is present in many wheat fields nearly every year, and sometimes local epidemics are severe. Approximately every 5 yr, the disease is widespread throughout the state (17). FHB is often most severe when wheat is grown after or near maize (*Zea mays* L.) (14,16). Yield generally decreases in proportion to increases in disease severity (4,5,7). FHB-infected wheat may make animals sick if it is used as feed (3); the infected wheat could also have reduced bread-making quality (16). Further, when FHB-infected wheat is used as seed, seedling blight problems are aggravated and seed treatment is often required to obtain good stands (3).

Fusarium graminearum Schwabe is commonly associated with FHB in wheat in Minnesota (6,9,17). In addition, 12 other *Fusarium* species may be associated with the disease, but of these only *F. culmorum* (Wm.G. Sm.) Sacc. is likely to be important and then primarily in Minnesota's northern growing areas. *F. graminearum* and *F. culmorum* infect individual spikelets and spread from the point of infection into other parts of the spike (17,18).

Wheat cultivars vary in their reaction to FHB (2,6,10,12,13,15,16), but in the upper midwestern United States current evaluations in artificial epidemics are lacking. Of modern cultivars observed in natural epidemics in production fields and yield nurseries, in different seasons and at different locations in Minnesota, Marshall has usually been less severely infected than other cultivars, whereas Wheaton has frequently been more severely infected. However, incidence and severity vary in both cultivars. Controlled experiments are necessary to obtain accurate evaluations of wheat cultivars for reaction to FHB (15).

The objectives of this research were to use artificial epidemics to evaluate resistance to FHB in local spring wheat cultivars and to compare FHB reactions of midwestern cultivars with those of some Chinese cultivars reported to be resistant.

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MATERIALS AND METHODS

Cultivars Marshall and Wheaton were evaluated in inoculated plots over 6 yr from 1985 to 1990. Cultivars from the upper Midwest were evaluated and compared over 3 yr from 1988 to 1990. Chinese wheats were field-evaluated in 1989 and 1990.

Spring wheat cultivars were planted during the first 2 wk of May at the rate of 12 g of seed in rows 3.1 m long and spaced 0.3 m apart. A randomized complete block with three replicates was used each year. The field where the experiment was made in 1989 had been planted with maize in 1988 and was fertilized with urea (82.4 kg N/ha) before planting. The field used for experiments during the other years had been planted to soybeans (*Glycine max* (L.) Merr.) during the previous year, and no supplementary nitrogen or other fertilizer was necessary. Recommended herbicides and mechanical methods were used to control weeds as necessary.

Plants were inoculated when the main spikes of the earliest cultivars or lines began emerging from the boot, and inoculations were continued every other evening for 2 wk until all cultivars had been inoculated six to eight times. Immediately after inoculation, plots were sprinkle-irrigated for 10–20 min. The next day they were sprinkled two to four times for 30–60 min per time. When inoculation procedures were completed for the season, the sprinkling procedure was continued every day until disease was evaluated.

Each year inoculum was prepared from 20–30 isolates of *F. graminearum* that had been collected from different locations in Minnesota. The isolates, stored on soil or silica gel until used, were grown on fresh potato-dextrose agar (PDA) in petri dishes for 3–4 wk, and 10 cultures of each isolate were blended together with about 15 L of water to form a suspension of spores, hyphae, and some agar. This suspension was held at 15–20 C for about 4 hr, and then in the evening, just before inoculation, it was diluted 1:10 in 150 L of water containing 25 ml of Tween 20. This inoculum suspension was sprayed onto the spikes of plants in the nursery with a tractor-drawn sprayer. About 4 L of inoculum was sprayed over 20 m^2 of plot area.

FHB incidence and severity were evaluated 24 days after inoculation. Incidence was the percentage of spikes with necrotic spikelets in 50 single spikes of main tillers chosen at random per plot, and severity was the percentage of spikelets that were necrotic in diseased spikes.

A disease index value was calculated by determining the percentage of spikelets that were necrotic in 50 spikes.

Analysis of variance and differences among means, as determined by Tukey's test each year, were used to differentiate among treatments. For Table 1, means of the cultivars calculated 1988–1990 and means of years calculated across cultivars were not presented because of the magnitude of the cultivar × year interaction.

RESULTS

Comparison of midwestern cultivars. Data combined across cultivars each year indicated that incidence, severity, and index of FHB varied significantly with the year of testing. Mean values were greatest in the wet season of 1989, least in the dry season of 1988, and intermediate in 1990 (Table 1).

Incidence varied considerably with cultivars each year. FHB incidence was least in Marshall and Stoa, greatest in Shield, and intermediate in the other cultivars in both 1988 and 1989 (Table 1). In 1990, incidence was least in Stoa and a few other cultivars, greatest in Guard, and intermediate in the remaining cultivars.

Severity of FHB also varied with cultivars each year. In 1988 and 1989, it was least in Stoa. In 1988, severity was greatest in Len and Shield, and in 1989 it was greatest in Shield (Table 1). Severity was least in Era and Marshall in 1990, but cultivars did not differ significantly.

Index of FHB varied among cultivars each year. Stoa was consistently among the cultivars with the lowest index each year (Table 1). In 1989, index was greatest in Shield and Telemark, but in 1990 it was greatest in Amidon, Chris, Guard, and Wheaton.

Comparison of Marshall and Wheaton. Data combined across years for each cultivar indicated that Marshall had less FHB than Wheaton. Also, data combined across cultivars indicated that FHB varied with years. The cultivar × year interaction was statistically significant. FHB incidence and disease index were significantly lower in Marshall than in Wheaton in 1985, 1986, and 1990 (Table 2), but these two methods of estimating FHB did not indicate cultivar differences in 1988 and 1989, years when drought occurred during flowering and kernel-fill stages of plant growth, or in 1989 when there was excess rain during the time of disease development. FHB severity was significantly lower in Marshall than Wheaton each year from 1985 to 1990, except in 1988 and 1989.

Comparison of Minnesota and Chinese wheats. FHB of Marshall was similar in incidence, severity, and index to the Chinese cultivars Fan 1 and Su Mai 3 (Table 3). The reaction of Wheaton, the more susceptible Minnesota cultivar, was similar to that of the other four Chinese wheats. FHB was significantly less severe in 1989 than in 1990.

DISCUSSION

During the decades between 1920 and 1950, hundreds of spring wheat cultivars and plant introductions and thousands of selections of hybrids of *Triticum* spp. were evaluated at the University of Minnesota for resistance to FHB caused by *F. graminearum* (2,6,12). Most of these wheat genotypes were susceptible, none were immune, but a few had reactions (measured as incidence or severity) low enough to be considered resistant. FHB reactions of some progenies from crosses between resistant and susceptible cultivars equalled or exceeded the reaction

Table 1. Fusarium head blight incidence, severity, and index in spring wheat cultivars inoculated with *Fusarium graminearum* at St. Paul, MN, in 1988, 1989, and 1990

Cultivar[z]	Incidence (%) 1988	1989	1990	Severity (%) 1988	1989	1990	Index (%) 1988	1989	1990
Amidon	15 ab	83 ab	47 ab	9 ab	30 bc	27 a	1.3 abc	25 bc	12 abc
Butte 66	13 ab	82 ab	43 a	9 ab	28 bc	18 a	1.0 ab	26 bc	8 ab
Celtic	16 ab	100 b	32 a	8 ab	30 bc	15 a	1.2 abc	29 bc	5 ab
Chris	14 ab	93 b	54 ab	12 ab	29 bc	26 a	1.6 abc	27 bc	14 bc
Era	9 ab	100 b	35 a	9 ab	29 bc	10 a	0.8 a	29 bc	4 a
Guard	11 ab	88 ab	80 b	10 ab	22 ab	23 a	1.0 ab	19 ab	19 c
Len	15 ab	98 b	37 a	15 ab	24 abc	22 a	2.2 bc	23 bc	8 ab
Marshall	5 a	99 b	51 ab	8 ab	25 abc	10 a	0.5 a	24 bc	5 ab
Nordic	6 ab	99 b	38 a	7 a	27 bc	16 a	0.4 a	27 bc	6 ab
Norseman	15 ab	97 b	53 ab	8 ab	24 abc	12 a	1.3 abc	24 bc	6 ab
Shield	18 b	99 b	53 ab	14 b	33 c	15 a	2.3 c	33 c	7 ab
Stoa	5 a	67 a	36 a	7 a	16 a	14 a	0.4 a	11 a	5 ab
Tammy	14 ab	97 b	49 ab	12 ab	23 ab	18 a	1.4 abc	22 abc	9 ab
Telemark	7 ab	100 b	41 a	8 ab	31 bc	16 a	0.6 a	31 c	8 ab
Wheaton	10 ab	98 b	55 ab	11 ab	31 bc	21 a	1.1 abc	30 bc	12 abc

[z] Cultivar data are the means of three replicates per cultivar. Incidence was based on 50 plants chosen at random per replicate, severity was based on the number of necrotic spikelets in diseased spikes, and index was based on the percentage of spikelets that were necrotic in 50 spikes per replicate. Means followed by the same letter are not significantly different ($P = 0.05$).

Table 2. Fusarium head blight incidence, severity, and index in Marshall and Wheaton spring wheat cultivars inoculated with *Fusarium graminearum* at St. Paul, MN, from 1985 to 1990[z]

Year	Incidence (%) Marshall	Wheaton	Mean	Severity (%) Marshall	Wheaton	Mean	Index (%) Marshall	Wheaton	Mean
1985	32 a	90 b	61	12 a	57 b	34	2 a	50 b	28
1986	17 a	64 b	40	13 a	29 b	21	6 a	19 b	11
1987	6 a	8 a	7	12 a	26 b	19	1 a	2 a	1.5
1988	5 a	5 a	5	8 a	9 a	8	1 a	1 a	1
1989	94 a	94 a	94	26 a	31 a	28	25 a	29 a	27
1990	45 a	52 b	49	10 a	24 b	16	5 a	12 b	9
Mean	23	52		14	29		6	19	

[z] Means for cultivars based on three replicates per year. Means followed by the same letter are not significantly different ($P = 0.05$). The cultivar × year interaction was significant ($P = 0.05$).

of the resistant parent. This FHB program was discontinued in the early 1950s for reasons that are not now clear. However, at that time, there were many changes in personnel and, in addition, there was considerable demand for resources to develop wheats that were resistant to stem rust, which occurred in great epidemics during the first half of the 1950s.

Our data confirm the earlier Minnesota experience (2,6) that wheat cultivars with some resistance to FHB can be identified in field nurseries when plants are inoculated and kept moist during the period of disease development. Stoa consistently had less FHB than other cultivars in replicated experiments between 1988 and 1990. Marshall and Wheaton were considered to be checks, because they differed in FHB severity in natural epidemics and in replicated trials between 1985 and 1990. FHB was generally more severe on Marshall than on Stoa, but on these two cultivars it was usually less severe than on Wheaton and other cultivars.

Adequate moisture is necessary for FHB development; adequate inoculum is assumed (1,9,13,16). Little FHB developed in these plots in the dry years of 1987 and 1988, despite frequent sprinkling to favor disease development. On the other hand, excess moisture may so favor disease development that genetic differences for resistance among cultivars are overwhelmed. This was evident in 1989 when FHB was unusually severe in our plots. Rain was frequent, and sprinkling was continued as scheduled during July as disease developed.

The severe epidemic of 1989 may have increased due to the maize debris in the field where plots were located (14,16). In 1988, the field was used to produce maize, and considerable inoculum may have been produced on the maize plants and debris. The amount of natural inoculum in the field was not measured, but it likely was abundant and supplemented what was applied during inoculations.

FHB reactions may be estimated by incidence, severity, or disease index. Of these, index appears to provide the most useful estimate, because it is essentially the product of incidence and severity ratings. The index consistently reflected the reactions of Marshall and Wheaton, cultivars that have differed in reaction to FHB in many natural and artifical epidemics in Minnesota. Incidence is probably the easiest to obtain, but in some epidemics it may be high even though severity is low. Perhaps incidence may be used as a measure of resistance only when severity is relatively high.

The FHB reaction of Marshall wheat was similar to that of Fan 1 and Su Mai 3, Chinese wheats reported to be resistant (4,5,15). Unfortunately, the levels of resistance observed do not appear to be adequate to protect cultivars against FHB damage in Minnesota when weather conditions are all very favorable for FHB development. Higher levels of resistance are needed.

Different genes likely condition the FHB resistance observed in Marshall, Stoa, Fan 1, and Su Mai 3, because the midwestern cultivars are not closely related to the Chinese cultivars. Different genes from these sources might be quickly combined into single lines by means of recurrent selection, and then the lines could serve as parents in a wheat improvement program with FHB resistance as a major objective.

Variation in the virulence of *F. graminearum* might affect successful development of FHB-resistant wheats. Wang and Miller (15) and Xu and Fang (19) found differences in pathogenicity when different isolates of *F. graminearum* were compared, but they concluded that the variation had little effect on disease development or the expression of resistance. Perhaps the importance of pathogenic variation of the FHB pathogen should be reexamined. We have obtained severe infection of Chinese wheats in glasshouse tests with Minnesota isolates (*unpublished*). Further, the lack of differences in disease development in Marshall, a wheat that sometimes becomes very scabby, and Fan 1 and Su Mai 3, resistant Chinese wheats, suggests that perhaps a more virulent isolate of *F. graminearum* occurs in Minnesota than in the locations where the Chinese wheats were tested.

Table 3. Fusarium head blight incidence, severity, and index in spring wheat cultivars from Minnesota and China inoculated with *Fusarium graminearum* at St. Paul, MN, in 1989 and 1990[x]

Cultivar[y]	Incidence (%)	Severity (%)	Index (%)
Minnesota cultivars			
Marshall	64 ab	15 a	11 a
Wheaton	81 d	26 b	22 b
Chinese cultivars			
Fan 1	52 a	17 a	9 a
Su Mai 3	67 bc	15 a	11 a
Shanghai 3	81 d	33 c	29 c
Shanghai 5	72 bcd	26 b	21 b
Suzhoe T3[1]	75 bcd	24 b	20 b
YMI 6	83 d	26 b	23 bc
Mean[z]			
1989	53 a	20 a	12 a
1990	93 b	26 b	26 b

[x] Values are the means over 2 yr.
[y] Means for cultivars based on three replicates each year. Means for cultivars or years followed by the same letter are not significantly different ($P = 0.05$). The year × cultivar interaction was not statistically significant.
[z] Year means were calculated across cultivars in three replicates.

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LITERATURE CITED

1. Anderson, A. L. 1948. The development of *Gibberella zeae* head blight of wheat. Phytopathology 38:595-611.
2. Christensen, J. J., Stakman, E. C., and Immer, F. R. 1929. Susceptibility of wheat varieties and hybrids to fusarial head blight in Minnesota. Minn. Agric. Exp. Stn. Tech. Bull. 59. 24 pp.
3. Dickson, J. G. 1942. Scab of wheat and barley and its control. U.S. Dep. Agric. Farmer's Bull. 1599. 22 pp.
4. Galich, M. T. 1989. Importancia y diffusion de la fusariosis de trigo en Argentina. Pages 7-26 in: Taller Sobre la la Fusariosis de la Espiga en America del Sur. M. M. Kohli, ed. Centro Internacional de Majoramiento de Maize y Trigo (CIMMYT). Mexico D.F.
5. German, S. 1989. Importancia de la fusariosis de la espiga en el Uruguay. Pages 49-57 in: Taller Sobre la Fusariosis de la Espiga in America del Sur. M. M. Kohli, ed. Centro Internacional de Majoramiento de Maize y Trigo (CIMMYT), Mexico D.F.
6. Hanson, E. W., Ausemus, E. R., and Stakman, E. C. 1950. Varietial resistance of spring wheats to fusarial head blight. Phytopathology 40:902-914.
7. Jacobsen, B. J. 1977. Effect of fungicides on Septoria leaf and glume blotch, fusarium scab, grain yield and test weight of winter wheat. Phytopathology 67:1412-1414.
8. Kohli, M. M. 1989. Analysis de la fusariosis del trigo en el Cono Sur. Pages 1-6 in: Taller Sobre la Fusariosis de la Espiga en America del Sur. M. M. Kohli, ed. Centro Internacional de Majoramiento de Maize y Trigo (CIMMYT). Mexico, D.F.
9. MacInnes, J., and Fogelman, R. 1923. Wheat scab in Minnesota. Minn. Agric. Exp. Stn. Tech. Bull. 18. 32 pp.
10. Mesterhazy, A. 1983. Breeding wheat for resistance to *Fusarium graminearum* and *Fusarium culmorum*. Z. Pflanszenzuecht. 91:295-311.
11. Reis, E. M. 1988. Doencas do trigo III. *Giberella*. Centro Nacional de Pesquisa de Trigo. EMBRAPA, RS Brasil. 13 pp.
12. Schroeder, H. W., and Christensen, J. J. 1963. Factors affecting resistance of wheat to scab caused by *Gibberella zeae*. Phytopathology 53:831-838.
13. Scott, I. T. 1927. Varietal resistance and susceptibility to wheat scab. MO Agric. Stn. Res. Bull. 111. 14 pp.
14. Sutton, J. C. 1982. Epidemiology of wheat head blight and maize ear rot caused by *Fusarium graminearum*. Can. J. Plant Pathol. 4:195-209.
15. Wang, Y. Z., and Miller, J. D. 1988. Screening techniques and sources of resistance to fusarium head blight. Pages 239-250 in: Wheat Production Constraints in Tropical Environments. A. R. Klatt, ed. Centro Internacional de Mejoramiento de Maize y Trigo (CIMMYT). Mexico

D.F.
16. Wiese, M. V. 1987. Compendium of wheat diseases. The American Phytopathological Society, St. Paul, MN. 112 pp.
17. Wilcoxson, R. D., Kommedahl, T., Ozmon, E. A., and Windels, C. E. 1988. Occurrence of *Fusarium* species in scabby wheat from Minnesota and their pathogenicity to wheat. Phytopathology 78:586-589.
18. Wilcoxson, R. D., Ozmon, E. A., and Pierce, A. R. 1989. Effect of necrotic spikelets and location of plots on infection of wheat by cultures of *Fusarium graminearum*. Int. J. Trop. Plant Dis. 7:55-60.
19. Xu, Y., and Fang, Z. 1982. Methods of testing the resistance of wheat varieties to the scab and the differentiation of the virulence of the causal organism. Acta Phytopathol. Sin. 12:53-57.