Variation in Tolerance to Wheat Streak Mosaic Virus Among Cultivars of Hard Red Spring Wheat

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ABSTRACT

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The effects of wheat streak mosaic virus (WSMV) infection on yields and 1,000-kernel wt of 19 spring wheat cultivars were determined in field studies after uniform mechanical inoculation of each cultivar. In 1986, yield reductions due to WSMV infection ranged from 48.5 to 98.7%, while 1,000-kernel wt reductions ranged from 17.9 to 42.4%. In 1987, reductions in yield ranged from 31.9 to 95.3%, while reductions in 1,000-kernel wt ranged from 10.8 to 49.3%. Although none of the cultivars demonstrated excellent tolerance to infection under these conditions, potentially useful tolerance was found in a few cultivars.

Wheat streak mosaic is a significant disease problem occurring in all of the major wheat producing regions of the world. Losses range from a trace to virtually 100%. Significant losses to the winter wheat crop of the Central Great Plains of the United States occur on an annual basis (7). In addition, an increased incidence of wheat streak mosaic in spring wheats has occurred in recent years in North Dakota and neighboring states. Although the importance of wheat streak mosaic as a disease of winter wheat is well established, its potential importance as a disease of spring wheat also should be recognized.

Practices that increase the chances of overlap between spring and winter crops as well as observed increases in disease incidence in spring wheat make it essential that we better understand the effects of wheat streak mosaic virus (WSMV) on currently grown spring wheat cultivars. While WSMV tolerance in wheat is known, no specific resistance genes have yet been identified. In the present studies, the effects of WSMV infection on the yield and 1,000-kernel wt of various spring wheat cultivars were determined as a means of identifying tolerant cultivars.

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MATERIALS AND METHODS

Nineteen different hard red spring wheat cultivars (*Triticum aestivum* L.) were evaluated for response to WSMV infection over a 2-yr period. Fifteen cultivars were evaluated in 1986. Eight of these, plus four additional cultivars, were evaluated in 1987. Previously, six of these 19 cultivars had been similarly evaluated at this location in one or more years (1,2,5,6).

In all cases, cultivars were grown in paired four-row field plots in Fargo, ND. Four replications were used in 1986, and three in 1987. Individual rows were 3.66 m long and 30.5 cm apart. The two center rows of one of each of the paired plots were inoculated by spraying the plants with a mixture of Carborundum and diluted sap from WSMV-infected plants grown in the greenhouse. An artist's spray gun was used at a pressure of 414 kPa (60 psi). Plants were inoculated in the three-leaf stage in 1986 and the two-and-a-half to three-leaf stage in 1987. Checks were not inoculated.

Yield and 1,000-kernel wt data were obtained after harvesting the two center rows of every plot, one plot inoculated and the other noninoculated. Only the middle 3 m of each row was harvested in order to avoid possible edge effects (total of 6 m of row harvested per plot). Harvested grain was weighed and data was converted to kilograms per hectare for relative yield comparisons. Thousand-kernel weights were determined by counting and weighing 1,000-kernel samples from each plot.

Differences between noninoculated control plants and infected plants were analyzed using the paired *t* test. Differences among cultivars were analyzed using both Duncan's multiple range and least significant difference tests. Statistically homogeneous groups of cultivars were similar with both tests.

RESULTS

Typical yellowing and streak mosaic symptoms had developed in inoculated plants by approximately 2 wk after inoculation, while mild to severe stunting became evident as the season progressed. Symptoms of WSMV were not observed at any time in noninoculated controls, guard rows, or neighboring plots. All cultivars tested were susceptible, but symptom severity varied. Cultivar Olaf exhibited extremely severe mosaic, yellowing, and stunting. Other cultivars, such as Butte and Oslo, developed some mosaic but very little yellowing and stunting. Formal disease severity ratings were not assigned.

In 1986, yield reductions due to

WSMV infection ranged from 48.5 to 98.7%, while 1,000-kernel wt reductions ranged from 17.9 to 42.4% (Table 1). The cultivars demonstrating the least percent yield reduction were Butte, Cutless, and Butte 86. Leif and Lancer showed the least 1,000-kernel wt reduction. On the other hand, the cultivar suffering the greatest percent yield reduction was Olaf, followed by Success and Katepwa. Percent reduction in 1,000-kernel wt was greatest in Norak.

Reductions in yield ranged from 31.9 to 95.3% in 1987. Reductions in 1,000-kernel wt ranged from 10.8 to 49.3% (Table 2). Oslo, Cutless, Butte 86, and Challenger exhibited the least percent yield reduction as well as the least 1,000-kernel wt reduction when infected. Performance of infected Olaf was poorest among all cultivars, whether comparisons were based upon percent 1,000-kernel wt or percent yield reductions.

Actual yields in 1986 ranged from 1,258.9 to 2,162.8 kg/ha (23.4 to 40.2 bu/a) for noninoculated control plants and 21.5 to 1,043.7 kg/ha (0.4 to 19.4 bu/a) for infected plants (Table 1). Wheat streak mosaic virus-infected cultivars with the best yield were Butte 86, Cutless, Challenger, Oslo, and Butte. Butte 86, Lancer, Norseman, Leif, and Butte produced the heaviest grain, even though infected. Thousand-kernel weights ranged from 18.8 to 27.4 g for non-inoculated checks in 1986, but only 13.1 to 20.5 g for infected plants (Table 1).

Yields were generally higher in 1987, ranging from 2,157.4 to 2,862.2 kg/ha (40.1 to 53.2 bu/a) for noninoculated checks and 102.2 to 1,818.4 kg/ha (1.9 to 33.8 bu/a) for infected plants (Table 2). Oslo, Butte 86, Cutless, Challenger, and Norseman were the top five yielding cultivars when infected. Cultivars with the highest 1,000-kernel wt when infected were Oslo, Butte 86, Challenger, Nordic, and Cutless. Thousand-kernel weights ranged from 24.2 to 31.7 g for non-inoculated checks vs. 14.8 to 27.3 g for infected plants (Table 2).

Table 1. Effect of wheat streak mosaic virus (WSMV) infection on yield and 1,000-kernel wt of hard red spring wheat cultivars in 1986 field trials

	Yield kg/ha[a]			1,000-kernel wt (g)[a]		
Cultivar	Control	WSMV Infected	Reduction[b] (%)	Control	WSMV Infected	Reduction[c] (%)
Butte	1,474.1	758.6	48.5	23.2	17.6	24.1
Butte 86*[d]	2,146.6	1,043.7	51.4	27.4	20.5	25.2
Challenger*	2,060.5	989.9	52.0	22.3	16.3	26.9
Cutless*	2,055.2	1,006.1	51.0	24.1	16.8	30.3
Eagle/ND586sib	1,334.2	425.0	68.1	22.1	15.7	29.0
Glenman*	1,350.4	602.6	55.4	22.7	17.3	23.8
HY320	1,258.9	408.9	67.5	18.8	13.1	30.3
Katepwa	2,060.5	365.8	82.2	26.8	17.5	34.7
Lancer	1,560.2	667.1	57.2	23.9	19.2	19.7
Leif*	1,414.9	500.3	64.6	22.3	18.3	17.9
Norak	2,055.2	398.1	80.6	23.6	13.6	42.4
Norseman*	2,162.8	640.2	70.4	24.6	19.0	22.8
Olaf*	1,635.5	21.5	98.7	24.9	NA[e]	NA
Oslo*	2,071.3	941.5	54.5	22.8	15.1	33.8
Success	1,388.0	220.6	84.1	21.0	13.3	36.7

[a] Differences between values for noninfected and infected plants are all significant ($P \leqslant 0.05$) in paired t test comparisons.
[b] LSD ($P \leqslant 0.05$) = 10.4.
[c] LSD ($P \leqslant 0.05$) = 8.4.
[d] * = Cultivars evaluated in both 1986 and 1987.
[e] NA = Data not available due to insufficient seed production.

Table 2. Effect of wheat streak mosaic virus (WSMV) infection on yield and 1,000-kernel wt of hard red spring wheat cultivars in 1987 field trials

	Yield (kg/ha)[a]			1,000-kernel wt (g)[a]		
Cultivar	Control	WSMV Infected	Reduction[b] (%)	Control	WSMV Infected	Reduction[c] (%)
Butte 86*[d]	2,743.8	1,802.3	34.3	31.7	26.8	15.5
Celtic	2,706.1	860.8	68.2	31.0	21.0	32.3
Challenger*	2,458.7	1,533.3	37.6	30.9	25.7	16.8
Cutless*	2,571.6	1,721.6	33.1	28.9	23.9	17.3
Glenman*	2,254.2	1,312.7	41.8	24.2	19.9	17.8
Leif*	2,469.4	1,049.1	57.5	28.4	21.7	23.6
Nordic	2,862.2	425.0	85.2	30.7	25.0	18.6
Norseman*	2,765.3	1,345.0	51.4	26.9	20.8	22.7
Olaf*	2,157.4	102.2	95.3	29.2	14.8	49.3
Oslo*	2,668.5	1,818.4	31.9	30.6	27.3	10.8
Tammy	2,318.8	1,264.3	45.5	30.1	23.3	22.6
Telemark	2,711.5	1,092.1	59.7	26.0	20.7	20.4

[a] Differences between values for noninfected and infected plants are all significant ($P \leqslant 0.05$) in paired t test comparisons, except in the comparison of Oslo noninfected and infected 1,000-kernel wt, which are significantly different at $P \leqslant 0.2$.
[b] LSD ($P \leqslant 0.05$) = 11.9.
[c] LSD ($P \leqslant 0.05$) = 9.9.
[d] * = Cultivars evaluated in both 1986 and 1987.

DISCUSSION

For the purpose of this discussion, a cultivar was considered to be more tolerant than another if it was able to sustain WSMV infection while suffering a smaller reduction in yield or 1,000-kernel wt than another cultivar under the same conditions. A highly tolerant cultivar would suffer no yield or 1,000-kernel wt reductions. The most tolerant cultivars tested in these experiments demonstrated only limited levels of tolerance, suffering yield reductions of at least 30% and 1,000-kernel wt reductions of at least 10%. Use of mechanical inoculation allowed a better estimation of this tolerance than the use of vector inoculation would have, because any effects on the plants were attributable to the interaction of virus, host, and environment, and not to vector-related variables.

Generally better yields and higher 1,000-kernel wt in WSMV-infected plants in 1987 can be attributed to the more favorable growing conditions that occurred in 1987. Such variation in growing conditions as a result of complex interactions of biological and environmental factors necessitates the use of standard cultivars each year in order to properly assess the performance of new cultivars.

Eight of the cultivars tested were evaluated in both 1986 and 1987. Those demonstrating the greatest tolerance in terms of percent yield reduction were essentially the same for each year. Although the rankings were slightly different, no statistically significant yield differences were evident among the most tolerant cultivars. More year-to-year variability was evident when 1,000-kernel wt comparisons were made. Again, no statistically significant differences were observed among the more tolerant cultivars, even though the rankings for each year were different.

Past experiments have been conducted in this region using similar inoculation methods and certain common cultivars (1,2,5,6). Butte and Oslo have been consistently among the most tolerant to WSMV infection in tests conducted during six different years, while Olaf has had the most consistently poor performance during these tests. Although newly released cultivars were emphasized in the current studies, past workers have examined more popularly grown cultivars. Several of these (PR2369, Marshall, Stoa) tested in 1984 and 1985 were intermediate in reaction between Olaf and Oslo (5,6).

Although pedigrees of some of the tested cultivars are complex and others unknown, some association between parentage of tested cultivars and degrees of tolerance possessed by those cultivars became evident upon examination of their pedigrees. A significant amount of Butte germ plasm is incorporated into Butte 86, which performed well in both years tested. Glenman, from the cross SRR4551/Fortuna, and Lancer, from the cross Fortuna/Chris, also performed better than many of the other selections. Both Fortuna and Chris were reported to be highly tolerant by Rahman et al (4), and Fortuna was reported to be tolerant by others as well (3). Justin and Waldron, both severely affected by WSMV (4), served as parental germ plasm for Olaf, which demonstrated essentially no tolerance in our study.

Clearly, a broad range in tolerance to WSMV infection exists among the tested cultivars. Although natural conditions generally do not involve as severe disease pressure as was present here, severe losses have occurred under environmental conditions conducive to vector reproduction and movement. In any event, the level of tolerance possessed by cultivars such as Butte and Oslo is among the best available and, therefore, can be considered potentially useful in commercial field situations. The most tolerant cultivars identified here could also serve as sources of tolerant germ plasm until better sources of tolerance and/or resistance are found.

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