Resistance of Winter Wheats to Cephalosporium Stripe in the Field

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ABSTRACT

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Very susceptible wheats (*Triticum aestivum*) were consistently susceptible but wheats with some resistance to Cephalosporium stripe (*Cephalosporium gramineum*) varied widely in disease reaction from season to season. In a highly susceptible wheat in a year favorable to the disease, as little as 430 kg/ha of infested straw produced maximum disease and an increase in disease was recorded with as little as 13–54 kg/ha of infested straw. Moderate resistance over a period of years is useful, especially when combined with rotation.

Cephalosporium stripe, incited by *Cephalosporium gramineum* Nisikado & Ikata (syn. *Hymenula cerealis* Ell. & Ev.), became a major disease in Washington when the winter wheat (*Triticum aestivum* L. 'Brevor') dominated the high-rainfall areas of eastern Washington in 1952–1962 (2). Brevor was so severely damaged in the summer-fallow, winter wheat system of farming that yields as low as 536–1,005 kg/ha resulted. Farmers in the affected areas rotated more, and Brevor was replaced by Gaines in 1963 and by Nugaines in 1966. Cephalosporium stripe subsided after a few years to insignificance. Gaines and Nugaines were the dominant wheats until they were replaced in 1976 by the higher-yielding cultivars Hyslop, McDermid, and especially, Stephens. With repeated growth of these cultivars, Cephalosporium stripe again became important and caused economic losses over a wider geographic area than in earlier years. This study was conducted to determine the relative resistance of some cultivars and selections and the effect of inoculum levels and seasons on their responses to disease.

MATERIALS AND METHODS

All experiments were conducted in a winter wheat-fallow succession near Pullman, WA. Seeding was between 6 and 15 September, near-normal for fallow fields in the Palouse region of eastern Washington. Weeds were controlled with herbicides and hand-cultivation. Because the wheat-fallow-wheat succession with early seeding favors strawbreaker foot rot (*Pseudocercosporella herpotrichoides* (Fron) Deighton), all plots were sprayed with benomyl. In the 1980–1981 and 1983–1984 growing seasons, stripe and leaf rusts were controlled by foliar applications of triadimefon.

Untreated seed was sown with a deep-furrow drill at a rate of 67 kg/ha in rows 40 cm apart in four-row plots varying in length from 3 to 5 m in the various trials. Fall stands were excellent in all trials.

Inoculum in the 1979–1980 and 1981–1982 seasons was natural inoculum from previous crops of diseased wheat. In the 1980–1981 season, four random blocks, 10 × 12 m each, were inoculated by spreading naturally infested straw at the rate of 1,129 kg/ha on the soil surface after the wheat had emerged. Four blocks were inoculated with 439 kg/ha of oat kernels infested in the laboratory with *C. gramineum* spread broadcast, and four blocks were inoculated by drilling infested oat kernels (6 g/m) in the row with the seed as done by Mathre and Johnston (4). Four similar blocks were not inoculated. Each wheat was seeded in each block.

In the 1982–1983 season, three levels of inoculum were compared. Natural inoculum consisted of that remaining after the diseased 1980–1981 crop. An adjacent block of land not in winter wheat in 1980–1981 was added to provide little natural inoculum ("clean" land). The heavy rate consisted of that from diseased winter wheat in 1980–1981 plus 1,326 kg/ha of oat kernels infested with *C. gramineum* broadcast on the soil surface after the wheat had emerged. The medium rate consisted only of the residual inoculum of the diseased 1980–1981 crop, and the low rate consisted of the "clean" land plus 215.4 kg/ha of oats broadcast on the surface.

In the 1983–1984 cultivar trial, the plots seeded were 2 yr out of winter cereals (peas, summer fallow) and should have contained little inoculum. Three random blocks received no inoculum, three received 30.2 kg/ha of broadcast dried oat inoculum, three received 119.8 kg/ha, and three received 478 kg/ha, making zero, light, medium, and heavy inoculum rates.

In the 1983–1984 level of inoculum trial, McDermid, highly susceptible to Cephalosporium stripe, was inoculated by scattering naturally infested straw pieces 7–10 cm long uniformly over the surface of the soil on 18 October 1983 after the wheat had emerged. The straw was added at rates varying from 0 to 860 kg/ha. When near maturity, 1-m lengths of the rows were cut and the number of infected and healthy stems was determined by visual examination.

Grain was harvested by hand from the center two rows of four-row plots 4–6 m long, except in the 1983–1984 season, when a plot combine was used to harvest all four rows. The percentage of diseased stems was determined by cutting stems before harvest when healthy stems were a bright straw color and diseased stems were visibly discolored.

In all years, high-yielding cultivars had a production capacity of more than 6,700 kg/ha.

RESULTS

1979–1980. The percentage of diseased stems at maturity was 49 in Nugaines, 58 in Sprague, 82 in Daws, 87 in Ticonderoga, and 90 in Sel. 101 ($LSD_{0.05}$ = 9%). Nugaines and Sprague were relatively resistant in this trial. Sprague is derived from a cross of PI 181268 × Gaines. Gaines and Nugaines are sister selections.

1980–1981. Disease incidence was equal in all three inoculation treatments (broadcast infested straw or oat kernels or infested oat kernels in the seed row), so the results were combined to total 12 replicates per entry. In this season with heavy inoculation, Sel. 80-112 (selected from a cross of Capelle-Desprez × Sprague) had 46%, Daws and Nugaines had 81%, Luke had 89%, and Sel. 101 had 97% diseased stems ($LSD_{0.05}$ = 9%).

1981–1982. No wheat was superior during this season (Table 1). Water ran along the drill rows during winter, eroding soil from the roots and exposing part of the root system to cold and air, resulting in unusual damage. Lewjain produced the highest yield of 2,606 kg/ha. The percentage of diseased stems

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was high in all wheats, with averages between 83 and 96%. Sel. 101 is highly susceptible to Cephalosporium stripe. It and Nord Desprez, also highly susceptible, are the parents of Stephens, Hyslop, and McDermid.

1982–1983. The three levels of inoculum resulted in little difference in average percentage of diseased stems: 46% in the heavy, 40% in the medium, and 35% in the low inoculum block (Table 2). Sel. 80-112 had the lowest average percentage of diseased stems (11%), and McDermid, the highest (61%). The amount of infested straw produced by each wheat per hectare varied from 326 kg/ha by Sel. 80-112 to 2,068 kg/ha by McDermid.

1983–1984: Cultivar trial. The winter was mild with many intermittent periods of above-freezing temperatures and few periods with snow cover; even the least hardy cultivar, Stephens, survived with vigor. Yields in the controls ranged from 4,510 kg/ha for Brevor to 8,548 kg/ha for Nugaines (Table 3). The low level of inoculum reduced average yields 42%, the medium level, 57%, and the high level, 61%; some cultivars responded differently to inoculum levels (Fig. 1). Lewjain withstood heavy inoculum better than the other cultivars as judged by total yield (Table 3). Stephens was affected significantly even by the low level of inoculum present in the controls (Table 4). It has a low inoculum level threshold for infection; 54% of its stems were diseased even with no added inoculum. All wheats with heavy inoculum had shriveled kernels salable only for feed purposes (Table 5).

1983–1984: McDermid × rates of inoculum. The control (zero inoculum added) had 26% diseased stems, and the highest inoculum levels had 89% infected stems (Table 6). The increase in disease produced by very low amounts of inoculum during this season was remarkable. Evidence of compensation is evident in every comparison of percentages of diseased stems and bundle weights of diseased and healthy wheat. Bundles consist of straw plus heads. In the zero-inoculum treatment, for example, 26% of the stems were diseased. The bundles made from the 26% diseased stems weighed 17% as much as those from healthy stems.

DISCUSSION

Winter weather causes "resistant" cultivar × disease interactions that are not understood. The percentage of diseased stems in Sel. 80-112 varied from 11 (Table 2) to 84 (Table 1). The most susceptible wheats (Sel. 101, Brevor, Hyslop, McDermid, and Stephens) were consistently susceptible. The data also

Table 1. Number of diseased and healthy stems and grain yield of wheats on *Cephalosporium* plot at Pullman, WA, in 1981–1982

Entry	Stems T	Stems %D	Yield (kg/ha)
Lewjain	417[a]	89	2,618
Winridge	366	92	1,824
Sprague	372	93	1,737
Sel. 80-112	326	84	1,669
Nugaines	369	96	1,548
Daws	222	88	1,535
Stephens	143	85	518
$LSD_{0.05}$			480

[a]T = total number of stems in 2 m of row, average of six replicates; %D = percent diseased.

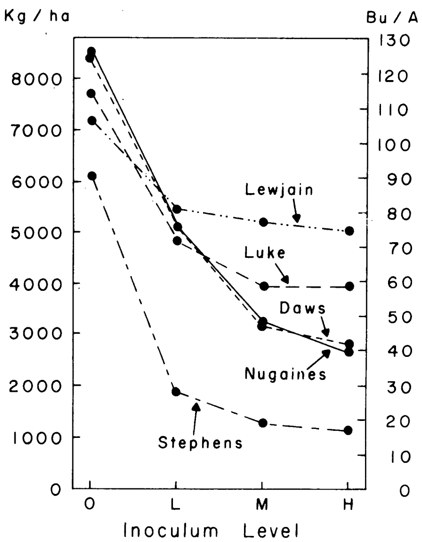

Fig. 1. Responses of five winter wheat cultivars to different inoculum levels of *Cephalosporium gramineum* in 1983–1984. O = control, L = low, M = medium, and H = heavy inoculum levels. Differentiation of levels of resistance was most distinct in the medium and heavy inoculum plots or under severe disease pressure.

Table 2. Effects of three inoculum levels of *Cephalosporium gramineum* on the percentage of diseased stems and the average production of infested straw by each cultivar at Pullman, WA, in 1982–1983

Entry	Diseased stems (%) Inoculum level[a] High	Medium	Low	Average	Wt of infested straw produced (kg/ha)
Sel. 80-112	9	9	14	11	326
Sprague	21	18	15	18	551
Winridge	31	27	17	25	834
Daws	40	20	27	29	984
Lewjain	42	34	33	36	1,734
Nugaines	47	36	38	40	1,519
Luke	49	41	31	40	1,877
Burt	61	41	27	43	1,286
Brevor	56	54	37	49	1,558
Stephens	53	66	52	57	2,009
Sel. 101	61	49	61	57	1,876
Hyslop	62	71	44	59	2,051
McDermid	66	56	60	61	2,068
$LSD_{0.05}$	20	19	15	11	589

[a]High = natural inoculum from diseased wheat plus 1,326 kg/ha of infested oat kernels, medium = natural inoculum from diseased wheat, low = 215 kg/ha of infested oats on "clean" land.

Table 3. Yields of winter wheats treated with four levels of inoculum of *Cephalosporium gramineum* at Pullman, WA, in 1983–1984

Entry	Yield (kg/ha) Inoculum level[y] Zero	Low	Medium	High	Average
Lewjain	7,135 a[z]	5,452 b	5,250 b	5,048 b	5,721
Luke	7,673 a	4,846 b	3,971 c	3,971 c	5,116
Nugaines	8,548 a	5,116 b	3,231 c	2,692 d	4,914
Sel. 80-112	7,135 a	5,789 b	3,298 c	3,298 c	4,914
Daws	8,346 a	5,048 b	3,164 c	2,827 d	4,846
Sprague	6,798 a	5,250 b	2,692 c	2,759 c	4,375
Winridge	5,721 a	4,173 b	4,106 b	2,558 c	4,173
McDermid	7,673 a	2,692 b	2,019 c	1,817 c	3,567
Hyslop	6,058 a	2,087 b	2,019 b	1,683 c	2,962
Stephens	6,058 a	1,885 b	1,279 c	1,144 c	2,558
Brevor	4,510 a	2,289 b	1,750 c	1,481 d	2,490
Average	6,866	4,039	2,962	2,692	...
$LSD_{0.05}$					173 kg/ha

[y]Zero = control, low = 30.2, medium = 119.8, and high = 478 kg/ha of broadcast dried oat inoculum. $LSD_{0.05}$ for inoculum levels = 101 kg/ha; $LSD_{0.05}$ for cultivar × inoculum interaction = 229 kg/ha.

[z]Yield values among inoculum levels for a given cultivar followed by the same letter are statistically similar at $P = 0.05$.

Table 4. Percentage of wheat stems infected by *Cephalosporium gramineum* with four levels of inoculum at Pullman, WA, in 1983–1984

Entry	Percentage of stems infected at each inoculum level			
	Zero[y]	Low	Medium	High
Sel. 80-112	10 a[z]	64 a	89 a	87 a
Nugaines	16 a	75 b	94 a	97 ab
Stephens	54 b	96 c	98 a	99 b

[y]Zero = control, low = 30.2, medium = 119.8, and high = 478 kg/ha of broadcast dried oat inoculum.
[z]Figures within columns followed by different letters differ significantly at $P = 0.05$ ($LSD_{0.05} = 13.8\%$).

Table 5. Test weight of grain produced by cultivars in Cephalosporium stripe plots with varying levels of inoculum during the 1983–1984 season

Entry	Test wt (kg/hl)				
	Inoculum level[a]				
	Zero	Low	Medium	High	Average
Winridge	79.2	75.7	73.4	68.9	74.3
Sel. 80-112	76.6	74.7	69.4	66.3	71.7
Sprague	77.9	74.1	68.9	65.7	71.6
Nugaines	79.9	72.1	67.6	62.9	70.6
Lewjain	74.1[b]	70.6	69.6	68.0	70.6
Luke	74.1[b]	68.3	69.3	69.3	70.2
Brevor	77.3	68.8	65.7	65.7	69.4
Daws	77.5	71.5	63.1	61.8	68.6
McDermid	76.6	65.9	64.4	60.5	66.8
Stephens	75.3	60.5	60.3	56.7	63.2
Hyslop	73.8	60.9	58.6	56.0	62.3
Average	76.6	69.4	66.3	63.8	...

[a]Zero = control, low = 30.2, medium = 119.8, and high = 478 kg/ha of broadcast dried oat inoculum.
[b]Test weight reduced by lodging. To convert kg/hl to lb/bu, multiply lb/bu × 1.288; 60 lb/bu = 77.3 kg/hl. No statistics applied because grain of all replicates was mixed, and test weights were based on the composite.

indicate that wheats with some resistance plus a high tillering capacity (Lewjain, Luke, and Nugaines) have an advantage. Even though many stems are infected, many tillers may escape. In addition, some yield compensation by healthy tillers occurs. Stephens has relatively few stems (Table 1) with large spikes, and it has less ability to compensate for loss of stems.

Local breeders have made significant progress in reducing susceptibility (Fig. 1). Stephens should have yielded much more, but even with the low inoculum present in the controls, 54% of its stems were diseased (Table 4). The ability of Stephens to contract disease from low inoculum levels contributes to increased disease after repeated growth of this highly susceptible cultivar. The relationship between the amount of inoculum and disease incidence in McDermid (highly susceptible) has important implications. Seemingly trivial amounts of infested straw spread uniformly on the soil surface increased disease in a season favorable to disease (Table 6). After widespread disease in the 1983–1984 season, many farmers burned the stubble after harvest. Burning greatly reduces inoculum (1). Depending on the uniformity of the burn, if it is followed by a highly susceptible wheat in a season highly favorable to disease, significant losses could still occur. In seasons unfavorable for disease development, moderate resistance must reduce inoculum below dangerous levels when winter wheat is grown only once every 3 yr.

Within several kilometers of Pullman, WA, Latin et al (3) reported 17% infected stems in Nugaines, 21% in Daws and Stephens, and 25–26% in Luke and McDermid. They seeded their wheats on 12–15 October, a month later than we did. Whether later seeding affects the disease reaction of Luke is not known, but in our trials, Luke was more resistant than McDermid.

Mathre and Johnston (4) obtained an increase in disease severity with each increment of inoculum: 0, 5, 10, and 20 g of oat inoculum per 3.6 m of row when the oat inoculum was added with the wheat seed in the drill row. The first 5 g increased disease 8.3%; the second 5 g, 6.2%; and the next 10 g, 7.2% (= 3.6% per 5 g unit), so disease increase per unit of inoculum was diminishing with each added increment of inoculum. In some of our trials, inoculum exceeded the level at which added inoculum increased disease, and in some trials, our "low" level was in reality quite high (Table 2).

Morton and Mathre (5) found two types of resistance: 1) an ability of a plant to escape with no striped tillers (= percentage of diseased plants) and 2) the reduction in number of diseased tillers in plants with at least one diseased stem. At first thought, the two could be expressions of the same thing, but they found them to be independent. In our studies, no effort was made to study disease on an individual plant basis.

The greatest differentiation of resistance, as reflected in yields, was obtained with severe levels of disease (Fig. 1). Of greater significance in epidemiology is the response of cultivars to very low levels of inoculum (Table 4). All wheats produce more than enough infested straw to provide inoculum when a high initial infestation exists and conditions favor disease (Table 2). Resistance is of greatest value in limiting disease when coupled with rotation and seasons unfavorable to disease development.

Table 6. Effect of amount of naturally infested straw on Cephalosporium stripe in McDermid winter wheat at Pullman, WA, in 1983–1984

Amount of straw (kg/ha)[a]	Diseased stems (%)	Bundle wts (%) of diseased vs. healthy
0	26	17
13	55	43
27	64	49
54	65	50
107	81	69
215	80	61
430	89	76
860	89	79
$LSD^{0.05}$	10	11

[a]To convert kg/ha to lb/acre, divide by 1.12.

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