Losses in Wheat Caused by Pyrenophora trichostoma and Leptosphaeria avenaria f. sp. triticea

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ABSTRACT

In North Dakota in 1970 and 1971, a complex of similar leaf spots caused by *Pyrenophora trichostoma* and *Leptosphaeria avenaria* f. sp. *triticea* caused moist weather losses averaging 12.9% in grain yield and 1.0% in test weight in spring wheats and durums. In dry weather these fungi caused little spotting and no losses. Maneb plus zinc ion fungicide controlled these losses. Inoculum usually traveled at least several meters in amounts sufficient to cause severe leaf spotting and yield loss. Abundant conidia of *P. trichostoma* were found in South Dakota in June and in North Dakota in July of 1972 on standing winter wheat. These conidia could serve as a source of secondary inoculum for infecting spring and durum wheats. Resistance to leaf spotting and influence of moisture on foliage in the glasshouse was related to resistance to yield loss and leaf spotting in the field.

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In North Dakota, *Pyrenophora trichostoma* (Fr.) Fckl. and *Leptosphaeria avenaria* Weber f. sp. *triticea* T. Johnson cause severe and similar leaf spotting on wheat (4, 5, 6, 7). *Helminthosporium sativum* P. K. B. causes varying but usually minor leaf spotting, and fungi resembling *Septoria nodorum* (Berk.) Berk.and *Ascocyta tritici* Hori and Enjoji are minor except *S. nodorum* on the state's western edge (4, 5, 7, and our *unpublished*). In the glasshouse, resistance to *P. trichostoma* in wheat has been related to the period of time free moisture remains with the fungus on the leaves: on the more resistant wheats the fungus requires over 36 hr of moisture; whereas on the most susceptible, 6 or less for severe leaf spotting to occur (4). In the field, severe leaf spotting is favored by prolonged moist weather (5).

The objectives of this study were to determine: (i) whether leaf spotting in the field caused by *P. trichostoma* and *L. avenaria* f. sp. *triticea* results in measurable losses in wheat; (ii) whether spotting, and losses are related to moist weather; (iii) whether Maneb plus zinc ion foliar spray would effectively reduce this leaf spotting and any associated yield losses; (iv) whether proximity of fungal inoculum affects severity of leaf spotting and wheat losses; and (v) whether resistance to leaf spotting in the glasshouse is comparable to resistance to yield loss and leaf spotting in the field.

MATERIALS AND METHODS.—In 1970 and 1971, at North Dakota Experiment Stations, drilled plots of wheat, each 10.8 to 14.4 m^2, were subjected to one of the following treatments: (i) Maneb plus zinc ion fungicide (Manzate 200) and Triton B 1956 spreader sticker applied to the foliage, at a rate of 2.24 kg of fungicide and 0.439 liters of spreader sticker per hectare (2 lb of fungicide and 6 oz of Triton per acre) in 935 liters per hectare of water (100 gal per acre) at a pressure of 14.0 kg/cm^2 (200 psi), at intervals of 7-10 days and after heavy rains, from seedling emergence to the mid-dough stage of wheat development; (ii) wheat straw infested with *P. trichostoma* and *L. avenaria* f. sp. *triticea* distributed sparsely on the ground above the planted wheat seed, and fungicide applied as in treatment one; (iii) no straw placed on the ground and no fungicide applied; and (iv) infested straw placed on the ground and no fungicide applied. Plots were separated from each other by distances of 1.2 to 9 m. In each trial, three randomized plots of each wheat genotype were subjected to a given treatment. At the Williston Experiment Station in 1970, a fungicide spray pressure of 2.8 kg/cm^2 (40 psi) was used.

In 1970, a split-block design was used for treatments and in 1971 a split-plot design. Linear regressions between y (grain yield) and x (leaf spot rating) for each genotype across the treatments were performed if a significant genotype × treatment interaction was detected. If the interaction was nonsignificant, the average yield of all genotypes was regressed on leaf spot severity rating. Deviations from linearity were tested by the error mean square from the appropriate analysis of variance.

Leaf spot severity was measured at various stages of growth by a rating system of one to six: rating 1 = 0% of the leaf surface killed by leaf spotting; rating 2 = 1%; rating 3 = 5%; rating 4 = 25%; rating 5 = 50%; and rating 6 = 100%. Disease severity between two ratings was recorded in decimal fractions. As reported earlier (5) and in the key devised by James for rating septoria leaf blotch of cereals (8), increase in percent of foliage killed often was associated with an increase in both number and size of leaf spots. Losses from leaf spotting were determined by comparing leaf spot severity in the upper leaves at the early dough stage of wheat development to grain yield and test weight (Table 1).

TABLE 1. Effect of fungicide and infested straw on wheat yield, test weight and leaf spot rating in five studies in North Dakota 1970, 1971

Location	Treatments 1 Fungicide spray	2 Fungicide, infested straw	3 Not treated	4 Infested straw	(% loss)[x]
Minot 1970					
Yield (kg/ha)	2499.6 a[y]	2488.5 a	2328.1 a	2095.9 b	16.2
Leaf spot rating[z]	2.6 a	2.9 a	3.9 b	4.2 b	
Williston 1970					
Yield (kg/ha)	1083.9 ab	1117.1 a	978.8 b	951.2 b	12.2
Test weight (kg/hl)	77.9 a	77.7 a	78.0 a	76.9 b	1.3
Leaf spot rating	3.0 a	3.1 a	4.8 b	4.9 b	
Minot 1971					
Yield (kg/ha)	2245.1 a	2173.3 a	2001.9 b	1968.7 b	12.3
Test weight (kg/hl)	80.0 a	79.5 a	79.9 a	80.2 a	−0.3
Leaf spot rating	3.0 a	2.8 a	3.7 b	3.8 b	
Carrington 1971					
Yield (kg/ha)	3859.5 a	3821.2 a	3506.0 b	3423.1 b	11.3
Test weight (kg/hl)	82.2 a	81.9 a	81.5 b	81.7 b	0.6
Leaf spot rating	1.9 a	1.9 a	3.6 b	3.8 b	
Fargo 1971					
Yield (kg/ha)	2820.3 a	2770.5 a	2449.8 b	2460.9 b	12.7
Test weight (kg/hl)	78.9 a	79.1 a	77.9 ab	76.9 b	2.5
Leaf spot rating	3.1 a	3.1 a	4.0 b	4.0 b	

[x]The yield or test weight in Treatment 1 minus that in Treatment 4, divided by that in Treatment 1, times 100 equals % loss.
[y]Means postscripted by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.
[z]Ratings range from one (no leaf spots) to six (leaves completely killed by leaf spots). See Materials and Methods section.

At all Experiment Stations, *P. trichostoma* and *L. avenaria* f. sp. *triticea* were the parasitic fungi commonly found in the leaf spots. *P. trichostoma* was found in the spots throughout the growing season, and both fungi were common from the heading stage to wheat maturity.

In 1970, the genotypes 'Waldron' and 'Chris' (hard red spring wheats) and 'Hercules' and 'Wells' (durums) were used at the Minot Station. At the Williston Station, the spring wheats Waldron, Chris, ND487, ND495, and 'C518', and the durums Hercules and Wells were used. At the Fargo Station the spring wheats Waldron, Chris, and ND487 and the durums Hercules, Wells, 'Leeds', and D6750 were used.

In 1971, the genotypes Waldron, ND487, Hercules and Wells were used at the Carrington Station. Waldron, Chris, Hercules, and Wells were used at Minot. At the Fargo Station, Waldron, Chris, Hercules, Wells, ND487, ND495, D6750, and 'C306' (a spring wheat) were used.

RESULTS.—In 1970, trace to moderate amounts of leaf spotting (ratings 1-3) appeared in the wheat seedlings at Minot, Williston, and Fargo. As the season progressed, prolonged periods of rain and/or dew increased at Minot and Williston. By the early dough stage, leaf spotting was severe in unprotected plots and related to yield losses (Table 1). At Fargo, after early spring rains, the weather was dry and windy with only traces of rain that quickly dried on the foliage. Practically no leaf spotting appeared on the leaves which developed subsequent to the spring rains, and no significant differences were detected among treatments for leaf spotting, yield, or test weight. In 1971, the weather was generally wetter than in 1970, and the foliage was moist for long but undetermined periods at all stations throughout the growing season. Leaf spotting was common and became severe by the early heading stage of wheat development. Severity of leaf spotting at the early dough stage was related to yield losses at the Minot, Carrington, and Fargo Stations (Table 1). Wheat losses related to the two leaf spot fungi in moist weather, averaged 12.9% in grain yield and 1.0% in test weight (average of percent losses in Table 1). Reduction in test weight was related to severity of leaf spotting but not as consistently as yield loss (Table 1).

The fungicide consistently reduced leaf spotting and the associated yield losses (Table 1). Low significance of yield reduction (significant at the 10% level but not the 5% level of probability) at Williston in 1970 may have resulted from the influence of drought stress, which affected yield more severely than leaf spotting. Rains were not prolonged at Williston in 1970, but dew often remained on the leaves until as late as 1100 hr.

Except for Minot in 1970, close proximity of fungal inoculum did not significantly increase severity of leaf spotting or wheat losses. In most trials, however, yields were consistently higher in plots without supplemental inoculum (Table 1).

Significant genotype × treatment interaction was detected in 1970, but not in 1971. At Minot in 1970, the more leaf spot resistant and/or tolerant genotypes Wells and Hercules (4, 5) had lower yield losses than the more susceptible Chris and Waldron (Fig. 1). When protected by fungicide, Wells and Hercules had essentially the same yield, averaging 2,804 kg/ha. When not protected by fungicide and grown in the presence of infested straw, yields were reduced 12% for Wells and 8% for Hercules, even though Hercules was more heavily infected. Yields of Chris and Waldron were reduced 23 and 28%, respectively, when the plants were least protected, in the nonspray, infested straw plots. Of the four genotypes, Waldron was the most severely infected and had the greatest yield reduction. Regression analysis of the trends of individual wheat genotype yield on leaf spot rating at Minot in 1970 indicated a lack of linearity. Although genotype × treatment interaction at Williston in 1970 was significant, the responses of individual genotypes in that trial were erratic, due probably to drought stress.

In 1971, severity of leaf spotting at the early dough stage of wheat development was linearly related to yield loss at all stations (Fig. 2), and both resistant and susceptible genotypes displayed similar losses. The differing losses in yield per leaf spot rating (the b values in Fig. 2) at each location indicated that other environmental factors had an effect on leaf spot-related yield losses.

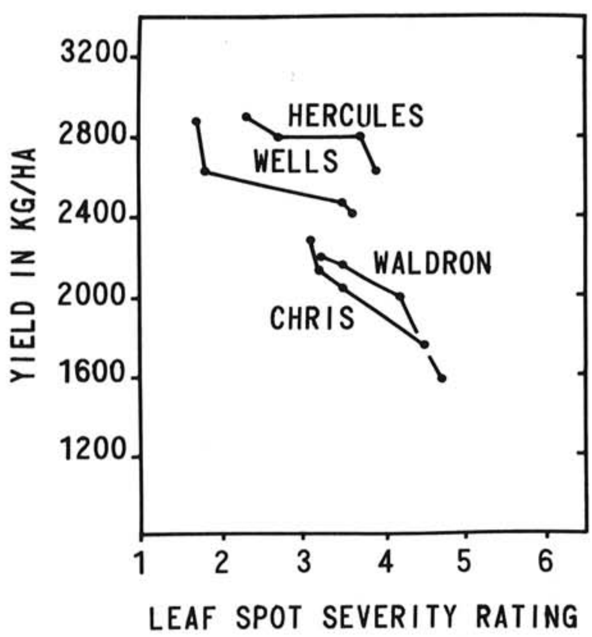

Fig. 1. Relation of grain yield to severity of leaf spotting at the early dough stage of wheat development in four wheat genotypes in 1970 at Minot, North Dakota. 1 = no leaf spots, 6 = leaves completely killed by leaf spots.

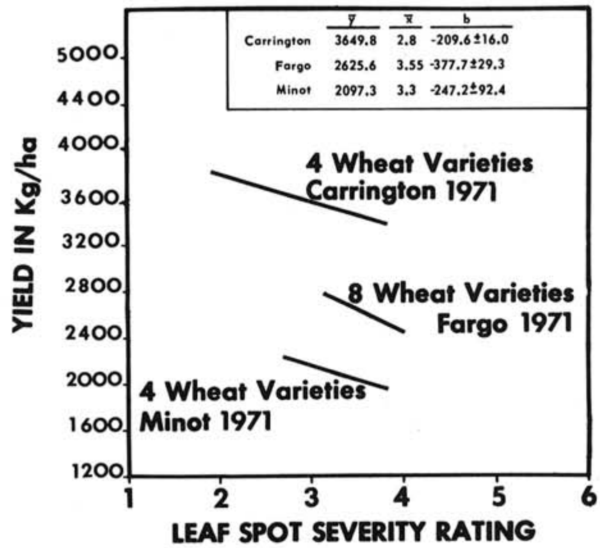

Fig. 2. Relation of wheat yield to severity of leaf spotting at the early dough stage of wheat development at three locations in North Dakota. 1 = no leaf spots, 6 = leaves completely killed by leaf spots.

One genotype, C306, was severely damaged in unsprayed plots at Fargo in 1971 by the two leaf spot diseases, and by leaf rust. Nonsignificance of the genotype × treatment interaction indicated that the relative yield and test wt loss of C306 was similar to that of the six other leaf rust-resistant genotypes.

DISCUSSION.—Leaf spotting caused by *Pyrenophora trichostoma* and *Leptosphaeria avenaria* f. sp. *triticea* results in important measurable losses in spring and durum wheats in North Dakota. This observation is further supported by a study in 1972, in which two applications of fungicide reduced severe leaf spotting by an average of 1.0 rating unit and increased yields by an average of 11.2% at two stations in North Dakota; at three other stations, spotting was minimal and fungicide had no effect on yield. Severe spotting and related yield losses are directly related to moderately wet or wet weather and do not occur in dry seasons. Maneb plus zinc ion foliar spray effectively reduces severe leaf spotting and associated wheat losses. Fungal inoculum usually travels at least several meters in amounts sufficient to cause severe leaf spotting and yield loss; closer inoculum usually adds only slightly to these effects but occasionally significantly increases them.

Resistance to leaf spotting from *Pyrenophora trichostoma* in the glasshouse is related to resistance to leaf spotting and to yield loss in the field. In the glasshouse, the cultivar Wells did not develop severe leaf spotting until after moisture had been on the leaves with the fungus for 18-24 hr. Hercules and Chris required 12-18 hr and Waldron 6-12 hr (4). In the field, Wells had less leaf spotting and less related yield loss than Chris, and Chris had less than Waldron (5, Fig. 1). Low yield loss in Hercules (Fig. 1) could be related to both a degree of resistance and a tolerance to leaf spotting. Loss of yield in the prolonged wet weather of 1971 (Fig. 2) corresponded to loss of resistance to Pyrenophora and Leptosphaeria leaf spotting in the field and to Pyrenophora leaf spotting under prolonged moisture in the glasshouse (4, 5). These relationships indicate that when ample rainfall or dew combined with high humidity and little wind result in moisture on the foliage for several hr (6-30 hr) the two leaf spot fungi cause major losses in more susceptible wheats and lesser losses in more resistant or tolerant wheats. When the weather is very wet and moisture is on the foliage for long periods of time (30-48 or more hr) these leaf spot fungi cause major losses in both the more susceptible and more resistant or tolerant wheats.

Severe leaf spotting in North Dakota usually occurs from the boot to late dough stage of spring and durum wheat development and is related to yield loss in wheat when rated at the early dough stage of growth. Occasionally, fields of seedlings are severely leaf-spotted, and *P. trichostoma* is usually the fungus isolated from these spots. Moisture stress studies (1) have indicated that stresses during the period from boot to dough stages and particularly around the bloom stage cause the greatest reduction in wheat yield and quality. Apparently, severe leaf spotting usually occurs at a time when its effect is most damaging to wheat production.

On the western edge of North Dakota a third pathogen, *Septoria nodorum* (Berk.) Berk. has appeared abundantly together with the conidial stage of *P. trichostoma* in some late-season leaf samples. *S. nodorum* is a serious world wide pest of wheat (16). It too should contribute to the leaf spotting in western North Dakota.

The picture is complicated further by the observations that *P. trichostoma* conidia were produced in large numbers on standing winter wheat in South Dakota in June 1972 and in North Dakota in July 1972. This suggests that, in addition to the already known ascospore inoculum in North Dakota (4, 5, 6, 7) and Canada (2) from spring and durum wheat straw, there could be a northward movement of conidial inoculum from winter wheats. This conidial inoculum is being produced on near-mature to mature winter wheats as the spring wheats go through the crucial boot-to-dough stages of growth.

Leptosphaeria avenaria f. sp. *triticea* causes damage to wheat in North Dakota (7) where showers of ascospores occur following rains (15). It is reported in a few other countries (9, 16). *Pyrenophora trichostoma* has been reported under various names (6) damaging wheat in many areas of the world (2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 17, 18, 19). It has caused damage alone (2, 3, 12) and in combination with other leaf-spotting fungi (5, 6, 10, 11, 13, 18). These two fungi cause important moist season losses in wheat in North Dakota. The literature suggests that they are presently more important causes of damage to wheat than is generally appreciated.

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