Influence of Foliar Fungicides and Seed Treatments on Powdery Mildew, Septoria, and Leaf Rust Epidemics on Winter Wheat

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ABSTRACT

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Three winter wheat cultivars were grown under an optimum crop management system for Pennsylvania at two locations during 1984 and 1985. The seed-treatment fungicide triadimenol and/or a foliar spray of triadimefon and mancozeb were applied for disease control. The foliar spray was applied as a tank mix at growth stage 6 (Feekes scale). Differences in AUDPC and grain yield among cultivars and cultivar × treatment interactions were observed. The cultivar Tyler, which had been resistant to powdery mildew before 1984, became the most susceptible of the three cultivars in 1985. Both seed treatment and foliar spray reduced the severity of powdery mildew, with the foliar spray contributing to the greatest reduction. In 33% of the cultivar × treatment × location evaluations, seed treatment and foliar spray combined reduced powdery mildew severity more than either did alone. The combination of seed treatment plus foliar spray reduced Septoria severity and leaf rust severity more than the individual treatments in 25 and 17%, respectively, of the cultivar × treatment × location evaluations. Foliar spray alone, as well as combined with seed treatment, increased yield in all trials.

Yields of soft red winter wheat (*Triticum aestivum* L.) in the eastern United States have remained consistently low during the past 30 yr, while yields have increased significantly in most European countries (3). This disparity in yield increases has led to significant research efforts on intensive cereal management (1,2,4–7,9,10). While the major emphasis has been directed at increasing the efficiency of agronomic practices (5–7,9,10), the importance of disease control and its interaction with other crop management practices has been demonstrated (1,2,4,9).

The three foliar diseases occurring on wheat in Pennsylvania are powdery mildew (*Erysiphe graminis* DC.:Fr. f. sp. *tritici* em. Marchal), Septoria leaf and glume blotch (*Leptosphaeria nodorum* Müller, anamorph: *Septoria nodorum* (Berk.) Berk.), and leaf rust (*Puccinia recondita* Rob. ex Desm. f. sp. *tritici* Eriks.). Foliar application of triadimefon (Bayleton) and mancozeb provided control of powdery mildew and reduced the severity of Septoria leaf blotch and leaf rust (11). Seed treatment with triadimenol (Baytan) also reduced powdery mildew and Septoria leaf blotch severity (4). Little is known, however, about the effects of combinations of fungicide treatments on control of the three major diseases of wheat in Pennsylvania. This study, therefore, was conducted to determine the efficacy of seed treatment and foliar fungicides alone and in combination on disease epidemics on soft red winter wheat.

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MATERIALS AND METHODS

Field experiments were conducted during 1984 and 1985 at two locations in Pennsylvania: Rock Springs in Centre County and Landisville in Lancaster County, approximately 200 km southeast of the first location where temperatures are higher throughout the season. At both locations, the soils were previously cropped with spring oats. Wheat crops were planted on 26 and 29 September in Rock Springs and on 13 and 14 October in Landisville in 1984 and 1985, respectively.

All fields were tilled with a moldboard plow, and 22 kg/ha of actual nitrogen was applied before planting. Limestone, phosphorus, and potassium also were incorporated at rates determined by soil test recommendations. Seeding was done with a tractor-mounted drill (H&N Equipment, Colwich, KS) that was custom-built to permit row-spacing adjustment and precision control of seeding rate and depth. All plots were planted at a rate of 168 kg/ha of seed in rows spaced at 12.7 cm. The plot size was 1.14 × 15.2 m with nine rows per plot. Plots were topdressed with 67.2 kg/ha of nitrogen in the form of NH_4NO_3 when plants reached growth stage 4 (GS-4) based on the Feekes scale (8) in the spring.

A split-plot design with four replications was used. Major plots were three wheat cultivars: Tyler (CI 17899), Roland (CI 17716), and Scotty (PI 469294). Subplots had four treatments arranged in a randomized complete block: control (nontreated), fungicide-treated seed, fungicide-sprayed foliage, and combined treated seed and sprayed foliage.

Certified seed treated with a commercial combination of carboxin (17% a.i.) and thiram (17% a.i.) (Vitavax 200), 2.5 ml/kg of seed, was used for all treatments to reduce the possibility of loose smut. The seed-treatment fungicide, triadimenol (30% a.i.) (Baytan 30), 77.8 ml/100 kg of seed, was sprayed onto Vitavax-treated seed while they were agitated in a rotary mixer. The seed was then air-dried for 48 hr before planting.

The foliar-spray fungicide was applied at GS-6 (8) with a tractor-mounted, CO_2-powered boom sprayer with hollow cone nozzles. Triadimefon (Bayleton 50WP), 140 g/ha, and mancozeb (80WP), 2.24 kg/ha, were applied as a tank mix in 280 L of water per hectare at 207 kPa.

Disease assessments were made at GS-7, GS-9, GS-10.1, and GS-11.1 on 20 tillers selected at random from each plot. Disease severity was assessed by estimating the percentage of leaf area infected by each of the three pathogens on the top two leaves of each tiller. The two values for each tiller were averaged. The values for the 20 tillers were averaged to provide a mean severity for each disease for each plot, and the area under disease progress curve (AUDPC) was calculated for each plot (12). The grain was harvested with a plot combine, and yields were adjusted to 13% moisture. AUDPC values and yield data were subjected to analysis of variance and mean separation test (Waller-Duncan k-ratio t test). In order to evaluate the relationship between disease severity and yield, the AUDPC values for all three diseases were tested in the R^2 procedure (SAS, Cary, NC) against the yield values. The R^2 procedure was conducted with AUDPC values pooled by year, by cultivar, by year × location, and by year × location × and cultivar. The R^2 values were calculated for each disease in relation to these factors.

RESULTS AND DISCUSSION

Previous research demonstrated that AUDPC was the best criterion for detecting differences in the effect of fungicides and/or seed treatments on foliar diseases of wheat (4). Therefore, all comparisons of foliar fungicide sprays, seed treatment, and the combination of treatments on the three wheat cultivars for each of the three foliar diseases were made with AUDPC values.

There were significant differences among cultivars and significant cultivar × treatment interactions at both locations in both years. Therefore, each cultivar was analyzed separately to evaluate the treatment effects. The three cultivars × 2 yr × two locations provide a total of 12 trials for evaluating treatment effects.

The cultivar Tyler was resistant to powdery mildew before 1984. Although the pathogen was never visible on the leaves during the 1983 growing season, it was present on the lower portion of the stems late in the epidemic. In 1984, however, powdery mildew was present on the leaves of Tyler, and both fungicide seed treatment and foliar sprays reduced disease severity at both locations (Table 1). In 1985, powdery mildew severity was greater on Tyler than on the other two cultivars at both locations. Foliar spray, seed treatment, and combined foliar and seed treatments reduced powdery mildew severity on Tyler by 85, 45, and 98%, respectively, in Landisville and by 81, 35, and 84%, respectively, in Rock Springs. Foliar spray and combined foliar and seed treatments reduced powdery mildew severity more than seed treatment alone.

The responses of Roland and Scotty, a susceptible and a resistant cultivar, respectively, were similar to those of Tyler, with both seed treatment and foliar sprays reducing powdery mildew severity at both locations in both years. In most situations, foliar spray reduced severity of powdery mildew more than seed treatment did. In 33% of the trials, seed treatment and foliar spray combined reduced disease severity more than either alone. When compared with the nontreated control, for example, foliar spray, seed treatment, and the combined treatment reduced powdery mildew severity by 75, 31, and 80%, respectively, on Roland at Landisville in 1984. The highest mildew severities in the 2 yr of this study were on Roland at Landisville in 1984. Foliar spray, seed treatment, and the combined treatment reduced powdery mildew severity by 77, 23, and 73%, respectively, on Scotty at Rock Springs in 1985.

Differences in actual AUDPC values between the nontreated control and the fungicide treatments among cultivars reflected the degree of susceptibility of the cultivars. For example, at Rock Springs in 1985, the differences in AUDPC values between the nontreated control and the foliar spray, seed treatment, and combined treatment were 103, 44, and 106, respectively, for Tyler; 72, 64, and 80, respectively, for Roland; and 38, 11, and 36, respectively, for Scotty. From these AUDPC values, a difference among cultivars was observed, whereas, based on percentage reduction, the foliar spray reduced mildew by 81, 81, and 77% on Tyler, Roland, and Scotty, respectively, with no differences among cultivars.

Foliar sprays reduced Septoria leaf blotch severities on all cultivars at both locations in both years. Seed treatment provided a greater reduction in disease severity than the foliar spray in 17% of the trials but did not reduce Septoria leaf blotch severity in 25% of the trials. The

Table 1. Effect of fungicide seed treatment and foliar spray on three foliar diseases of soft red winter wheat at two locations (Landisville and Rock Springs) in Pennsylvania during 1984 and 1985

		AUDPC[y]			
Cultivar	Treatment[x]	Powdery mildew	Septoria leaf and glume blotch	Leaf rust	Yield (kg/plot)
		Landisville, 1984			
Tyler	NT	22.5 a[z]	28.9 a	256.9 a	5,840 c
	FS	3.2 c	14.8 b	193.4 b	6,297 b
	ST	12.9 b	16.9 b	242.1 a	6,030 c
	FS&ST	4.2 c	16.5 b	190.5 b	6,572 a
Roland	NT	149.3 a	89.2 a	220.1 a	5,376 c
	FS	36.7 c	73.5 b	180.5 c	6,051 a
	ST	102.5 b	70.6 b	196.3 b	5,642 b
	FS&ST	30.1 c	62.8 c	183.4 c	6,110 a
Scotty	NT	17.6 a	25.4 a	2.3 a	6,156 b
	FS	2.0 c	20.6 b	0.2 b	6,265 a
	ST	8.7 b	20.9 b	1.9 a	6,100 b
	FS&ST	1.1 c	18.5 b	0.4 b	6,320 a
		Rock Springs, 1984			
Tyler	NT	12.7 a	222.4 a	100.6 a	5,236 b
	FS	2.1 c	192.5 b	77.5 b	5,420 a
	ST	5.3 b	203.1 b	84.2 b	5,266 b
	FS&ST	4.1 b	198.2 b	80.5 b	5,432 a
Roland	NT	93.4 a	185.2 a	88.2 a	4,950 c
	FS	8.6 c	175.4 b	69.3 b	5,189 b
	ST	22.0 b	189.5 a	81.3 a	5,003 c
	FS&ST	5.3 d	165.4 c	71.1 b	5,276 a
Scotty	NT	3.6 a	168.3 a	0.9 a	5,510 c
	FS	0.8 bc	150.7 b	0.0 b	5,613 b
	ST	1.2 b	152.1 b	0.7 a	5,701 ab
	FS&ST	0.6 c	155.6 b	0.1 b	5,720 a
		Landisville, 1985			
Tyler	NT	30.6 a	46.5 a	973.5 a	5,103 c
	FS	4.2 c	36.3 c	760.4 c	5,464 b
	ST	16.8 b	42.5 ab	823.2 b	5,315 bc
	FS&ST	0.6 d	38.6 bc	758.1 c	5,727 a
Roland	NT	12.9 a	59.3 a	342.3 a	5,679 c
	FS	2.9 c	42.6 b	292.8 b	5,900 a
	ST	6.1 b	57.2 a	311.2 ab	5,806 b
	FS&ST	0.9 c	40.5 b	253.4 c	5,975 a
Scotty	NT	24.8 a	23.7 a	6.7 a	5,749 c
	FS	4.5 c	12.5 b	2.8 c	5,934 a
	ST	10.5 b	16.9 b	4.0 b	5,985 a
	FS&ST	1.1 d	13.2 b	2.8 c	5,850 b
		Rock Springs, 1985			
Tyler	NT	126.5 a	133.0 a	100.5 a	5,179 d
	FS	23.7 c	45.1 c	16.3 c	5,606 b
	ST	82.5 b	96.5 b	70.3 b	5,270 c
	FS&ST	20.1 c	40.3 c	6.7 d	5,767 a
Roland	NT	89.3 a	334.5 a	5.1 b	5,781 b
	FS	17.4 c	316.4 b	1.2 c	5,925 a
	ST	25.6 b	251.8 c	6.2 a	5,698 b
	FS&ST	9.2 d	263.0 c	0.9 c	5,902 a
Scotty	NT	49.7 a	140.1 a	2.8 a	5,657 c
	FS	11.2 c	113.1 b	0.9 b	5,950 b
	ST	38.4 b	108.0 b	0.5 bc	5,728 c
	FS&ST	13.5 c	82.3 c	0.1 c	6,107 a

[x] NT = no treatment; FS = foliar spray, triadimefon (140 g/ha) and mancozeb (2.24 kg/ha) applied at Feekes growth stage 6; ST = seed treatment, triadimenol (77.8 ml/100 kg of seed); FS&ST = combined foliar spray and seed treatment at rates given for each.

[y] Area under disease progress curve (12).

[z] Means in columns within a given cultivar × year × location followed by the same letter are not significantly different according to the Waller-Duncan *k*-ratio *t* test ($k = 100$).

combined treatment provided more disease control than the individual treatments in 25% of the trials. For example, at Rock Springs in 1985, foliar spray, seed treatment, and the combined treatment reduced Septoria leaf blotch severities by 66, 27, and 70%, respectively, on Tyler; by 5, 25, and 21%, respectively, on Roland; and by 19, 23, and 51%, respectively, on Scotty. In both years, Septoria leaf blotch levels were higher in the Rock Springs trials than in the Landisville trials. All three cultivars were susceptible to Septoria leaf blotch, but severity was higher in Roland than in the other two cultivars.

Foliar fungicides were effective against leaf rust in all trials, and seed treatment reduced leaf rust severity in 58% of the trials. In 17% of the trials, control was better with the combined treatment than with either treatment alone. For example, at Landisville in 1985, foliar spray, seed treatment, and the combined treatment reduced leaf rust severities by 22, 15, and 22%, respectively, on Tyler; by 14, 9, and 26%, respectively, on Roland; and by 58, 40, and 58, respectively, on Scotty. The difference among the cultivars in the reduction in leaf rust severities may be a reflection of their susceptibility to leaf rust. For example, in terms of actual AUDPC values, the differences between the nontreated control and the foliar spray, seed treatment, or combined treatment for Landisville in 1985 were 213, 150, and 215, respectively, for Tyler; 49, 31, and 89, respectively, for Roland; and 4, 3, and 4, respectively, for Scotty. Scotty was more resistant to leaf rust than Roland or Tyler, and Tyler was most susceptible. However, disease severity on the Roland was also very low in 1985 in the Rock Springs trials. We have no explanation for this in light of the data from 1984 for this cultivar and the similarity between the leaf rust reactions in 1984 and 1985 for Tyler.

Foliar sprays contributed to a significant yield increase in all trials, whereas seed treatments increased yields in only 42% of the trials. The combined treatment provided significant yield increases in all trials. When averaged over location and years, foliar spray, seed treatment, and the combined treatment increased yields by 6, 2, and 9%, respectively, on Tyler; by 5, 2, and 9%, respectively, on Roland; and by 3, 2, and 4%, respectively, on Scotty. Foliar treatments reduced all three diseases on all cultivars at both locations in both years. At Rock Springs, seed treatment reduced all three diseases on Tyler in 1984 and on both Scotty and Roland in 1985, but there was no significant increase in yield. Conversely, powdery mildew was the only disease affected by seed treatment on Roland at Landisville in 1985 and yield was significantly increased.

Foliar spray with triadimefon and mancozeb effectively reduced the severity of powdery mildew, Septoria leaf blotch, and leaf rust epidemics and subsequently contributed to a yield increase for all cultivars at both locations over 2 yr. Triadimefon was expected to be effective for powdery mildew and leaf rust, whereas mancozeb was expected to be effective for Septoria leaf blotch and leaf rust.

Triadimenol seed treatment effectively reduced the severity of powdery mildew epidemics on all cultivars at both locations over the 2 yr but not of Septoria leaf blotch or leaf rust epidemics. Septoria leaf blotch and leaf rust severities were reduced for specific cultivars but not consistently at the two locations or in the 2 yr. The major difference among these three diseases is that mildew is often present in the fall on winter wheat and may serve as inoculum in the spring (J. A. Frank, *unpublished*), whereas the other two diseases are present the following spring only. Seed treatment contributed to a yield increase but not uniformly over all cultivars, locations, or years.

The combination of foliar fungicide and seed treatment effectively reduced the severity of all three foliar diseases and subsequently contributed to a yield increase for all cultivars at both locations in both years. This was not unexpected, since the foliar fungicide alone effectively contributed to a yield increase for all cultivars. There were only a few cases where the combined treatment contributed to a significant increase in yield over that contributed by the foliar spray treatment. The combined treatment led to higher yield increases for Tyler at Landisville and for Scotty at Rock Springs in both years.

By relating the yield values to diseases pooled by years, the strongest relationship occurred in 1984 between Septoria and yield ($R^2 = 0.72$). In 1985, however, this same comparison had an R^2 of 0.01. When the comparisons were made with values pooled by year and location, the best relationships occurred at Landisville for both years. In 1984, however, this association involved mildew and yield ($R^2 = 0.66$), whereas in 1985 the best association ($R^2 = 0.65$) involved leaf rust.

Because of its genetic disease resistance, Scotty had very low AUDPC values in both years and therefore will not be discussed in regard to relationships between diseases and yield. When the data are sorted by year, location, and cultivar, powdery mildew was the major disease factor in relation to yield in 1984 at Landisville. R^2 values were 0.58 for Tyler and 0.89 for Roland. The addition of the other two diseases did not improve the relationship to yield. In 1985 at Landisville, the relationship between Tyler and powdery mildew improved ($R^2 = 0.74$) but the dominant disease on Roland was leaf rust ($R^2 = 0.79$).

In 1984 at Rock Springs, all relationships were low. The R^2 for combined leaf rust and Septoria was 0.52 on Tyler and that for leaf rust alone was 0.53 on Roland. In 1985 at Rock Springs, the only meaningful relationship existed between leaf rust and yield ($R^2 = 0.74$) on Tyler.

Because the three cultivars differ in degree of susceptibility to the three pathogens, there were differences among cultivars for a particular disease with the greatest influence on yield reduction. This varied between locations and over years. In 1985, Tyler had higher severities for leaf rust at Rock Springs but higher severities for mildew at Landisville. Severities of the three diseases varied on Roland. In 1984 at Landisville, for example, severities for all three diseases were higher for Roland than for the other cultivars; in 1985 at Landisville, however, leaf rust appeared to have the greatest influence on yield. Overall, Septoria leaf blotch appeared to influence yield the most for Scotty. As expected, the disease that had the highest severity on a particular cultivar was affected the most by the fungicide treatments. This points to the importance of experimenting with fungicide rates and schedules on an array of cultivars over several years and locations for developing recommendations.

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