Effects of Leaf Rust and Septoria Leaf Blotch on Yield and Test Weight of Wheat in Arkansas

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ABSTRACT

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Leaf rust, caused by *Puccinia recondita*, and Septoria leaf blotch, caused by *Septoria tritici*, are the most serious foliar fungal diseases of wheat in Arkansas. This study was conducted to determine the relationship of leaf rust and leaf blotch severities at the soft dough stage to yield and test weight losses. Field experiments were conducted on three wheat cultivars during two growing seasons at two locations. For each cultivar, foliar fungicides caused differences in leaf rust and leaf blotch severities, yield, and test weight. Regression was used to determine the relationship of leaf rust and leaf blotch severities to yield and test weight losses. Average yield losses for cultivars Florida 302 and Rosen were 0.30 and 0.25% for each 1% increase in rust severity, respectively. The average test weight loss was 0.08% on Florida 302 and 0.03% on Rosen for each 1% increase in rust severity. Average yield losses caused by Septoria leaf blotch were 0.43, 0.47, and 0.32% for each 1% increase in leaf blotch severity on Florida 302, Rosen, and Caldwell, respectively. The average test weight loss for each 1% increase in leaf blotch severity was similar on Florida 302 (0.05%), Rosen (0.05%), and Caldwell (0.06%). Results of this study support the use of foliar fungicides on wheat in Arkansas to control leaf rust and leaf blotch, and to protect yield and test weight potential. Estimates of rates of yield and test weight losses should be useful for making disease management decisions.

Epidemics of leaf rust, caused by *Puccinia recondita* Roberge ex Desmaz. f. sp. *tritici*, and Septoria leaf blotch, caused by *Septoria tritici* Roberge in Desmaz., are usually widespread each season on soft red winter wheat (*Triticum aestivum* L.) in Arkansas. Under Arkansas conditions, wheat plants generally are not affected by foliar diseases from the seedling stage until tillers are elongated in the spring. Leaf blotch usually is the first foliar disease observed and typically occurs between Feekes growth stage (GS [6]) 5 (tillers erect) and GS 8 (flag leaf emergence). Leaf rust typically develops after leaf blotch. Trace amounts of powdery mildew, caused by *Erysiphe graminis* DC. f. sp. *tritici* Em. Marchal, may be found on lower leaves at GS 8; but the disease has been observed on upper leaves only infrequently (7).

Several authors have described the effects of leaf rust (2,10,12) or Septoria leaf blotch (4,11) on yield loss, but no studies have been done where both diseases occurred together. Although several studies (2,4,11,12) also have determined the effects on kernel weight loss, none have reported the effects of foliar diseases on test weight loss.

Test weight is used as a measure of grain quality by both domestic and foreign buyers of U.S. wheat (5), and is a major concern to wheat growers in Arkansas because the price paid for grain is discounted if test weight is below standard. The wheat grown in Arkansas and surrounding states is sold on the basis of U.S. no. 2 grade standards which require, among other criteria, a minimum test weight of 875 g/L (58 lb/bu) (1). Grain is discounted at progressively higher rates for wheat having test weight below 875 g/L. Although discount rates (percentages deducted from quoted price) for low test weight vary from year to year and from buyer to buyer, examples of typical discount rates in 1991 are 0.8% for wheat with test weight of 874 g/L (57.9 lb/bu) and 9% for wheat with test weight of 830 g/L (55 lb/bu) (N. V. McKinney, *personal communication*).

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The objectives of this study were to determine the relationships of leaf rust and Septoria leaf blotch severities to yield loss and test weight loss of wheat.

MATERIALS AND METHODS

Field plots. Field experiments were conducted during the 1989 and 1990 seasons (year of harvest) at the Pine Tree Station, Pine Tree, Arkansas, and in 1990 and 1991 at the Vegetable Substation, Kibler, Arkansas. Pine Tree is in the Mississippi Delta approximately 80 km west of Memphis, Tennessee. Kibler is in the Arkansas River Valley approximately 15 km east of Fort Smith. The soft red winter wheat cultivars Florida 302, Caldwell, and Rosen were used. In 1989, these cultivars occupied approximately 50, 25, and less than 1% of the wheat hectarage in Arkansas, respectively.

The experimental design for each cultivar was a randomized complete block with four replications and eight fungicide treatments. Each cultivar was planted in a block (i.e., cultivars were not randomized) and was treated as a separate experiment. Treatments were: 1) nonsprayed check; 2) alkylaryl polyethoxylate and sodium salt of alkylsulfonated-alkylate (Latron CS-7 spreader binder) applied early and late at 234 ml of product per hectare; 3) propiconazole (Tilt 3.6E) applied early at 126 g a.i./ha; 4) propiconazole applied early at 63 g a.i./ha; 5) triadimefon (Bayleton 50DF) at 70 g a.i./ha plus mancozeb (Dithane 75DF) at 1.68 kg a.i./ha applied late; 6) propiconazole applied early at 126 g a.i./ha followed by triadimefon at 70 g a.i./ha plus mancozeb at 1.68 kg a.i./ha applied late; 7) tebuconazole (Folicur 3.6F) at 126 g a.i./ha applied early; and 8) tebuconazole at 126 g a.i./ha applied late. Latron CS-7 at 234 ml of product per hectare was added to all fungicides except propiconazole. Treatments 3 and 5 are the recommended treatments for commercial application. Treatments were applied in 187 L/ha using a self-propelled highboy sprayer. Early applications were made at GS 8–9, and late applications were made at GS 10–10.5, depending on the location, year, and cultivar (Table 1).

Plots were planted using a small plot drill and were 7 rows (1.25 m) by 4.25 m long. Plots were fertilized at GS 4 with approximately 112 kg/ha of N at Pine Tree and 90 kg N plus 22 kg S per hectare at Kibler. Recommended herbicides were used for weed control as needed. At GS 11.2, leaf rust, leaf blotch, and powdery mildew severities were rated on a whole-plot basis as the percentage of foliage diseased. Severity percentages (and their ranges) were 0, 2 (trace–4), 7 (5–10), 15 (11–20), 30 (21–40), 50 (41–60), 70 (61–80), 85 (81–90), 93 (91–96), and 98 (97–100). Plots were trimmed to 3 m long before harvest and were harvested with a plot combine. Grain moisture and test weight were measured with a GAC II grain analysis computer, and yield was adjusted to 13% moisture.

At Pine Tree in 1989, plots were planted on 12 October, and fungicides were applied on 17 April (early) and on 26 April (late). Disease severities were recorded on 19 May, and plots were harvested on 16 June. At Pine Tree in 1990, plots were planted on 10 October, and fungicides were applied on 4 April (early) and on 26 April (late). Disease severities were recorded on 15 May, and plots were harvested on 12 June.

At Kibler in 1990, plots were planted on 27 October, and fungicides were applied on 3 April (early) and on 25 April (late). Disease severities were recorded on 18 May, and plots were harvested on 11 June. At Kibler in 1991, plots were planted on 24 October, and fungicides were applied on 4 April (early) and on 26 April (late). Disease severities were recorded on 9 May, and plots were harvested on 2 June.

Crop loss estimates. Losses in yield for each cultivar in each environment were calculated as percent loss $= [1 - (Y_d/Y_h)] \times 100$, where Y_h is the mean yield of the plots sprayed with propiconazole early followed by triadimefon plus mancozeb late, and Y_d is the yield for individual plots of the other treatments. Plots treated with propiconazole early followed by triadimefon plus mancozeb late were chosen as the disease-free check because this treatment provided the longest protection period and generally gave the best disease control (E. A. Milus, *unpublished*).

For each cultivar, location, and year, percent yield loss was regressed on leaf rust and Septoria leaf blotch severity using simple linear regression (9,13). An additional multiple regression model using both leaf rust and leaf blotch severities as independent variables was fitted to the data. For each regression equation, plots of residuals were examined to determine whether there were systematic patterns indicative of lack of fit. A quadratic regression was fitted to the data if plots of residuals suggested that a quadratic regression would fit the data better than a linear regression. For each cultivar and disease, an F test was performed to determine if there were differences among the slopes. For sets of lines having a significant F statistic, follow-up comparisons of the slopes were made using a two-sample t test. Test weight loss was analyzed similarly.

Table 1. Wheat growth stage and disease severities on nonsprayed check plots at the time of fungicide applications and disease severity evaluations for three cultivars[x]

Location Year	Cultivar	Feekes growth stage	Disease severity[y] Leaf rust	Septoria leaf blotch
Kibler				
1990	Florida 302	9	0	0
		10.5	1	20
		11.2	90	30
	Rosen	8	0.1	0
		10.5	0.1	20
		11.2	70	25
	Caldwell	8	0	0
		10.3	0	20
		11.2	1	50
1991	Florida 302	9	0.1	0.1
		10.5	0.1	1
		11.2	45	ND[z]
	Rosen	9	0.1	0.1
		10.5	0.1	1
		11.2	50	ND
	Caldwell	8	0.1	0.1
		10.3	0.1	2
		11.2	7	78
Pine Tree				
1989	Florida 302	9	0	10
		10.5	0	20
		11.2	25	40
	Rosen	9	0	10
		10	0.1	15
		11.2	98	50
	Caldwell	8	0	10
		10	0	20
		11.2	4	30
1990	Florida 302	9	1	1
		10.5	5	40
		11.2	98	98
	Rosen	8	1	1
		10.5	5	30
		11.2	90	94
	Caldwell	8	0	1
		10.3	0	30
		11.2	15	75

[x] Early applications at growth stage (GS) 8–9, late applications at GS 10–10.5, and disease evaluations at GS 11.2.
[y] Percent foliage diseased.
[z] Not determined because of low disease severity in all plots.

RESULTS

Florida 302, Rosen, and Caldwell were susceptible to Septoria leaf blotch. Rosen was susceptible, and Caldwell was moderately resistant to leaf rust. Florida 302 was resistant to prevalent races of *P. recondita* in 1989 and susceptible to new races in 1990 and 1991. Powdery mildew was found occasionally on lower leaves of Caldwell (severities less than 5%) at the times of fungicide application, but it did not spread to the upper leaves. Powdery mildew never developed to more than trace severities on Florida 302 or Rosen and was considered to have an insignificant effect on crop loss for all three cultivars.

The effect of leaf rust on yield and test weight losses of Caldwell could not be determined, because less than 30% leaf rust developed in nonsprayed plots. Likewise, the effect of Septoria leaf blotch on yield and test weight losses of Florida 302 and Rosen at Kibler in 1990 and 1991 could not be determined, because less than 30% leaf blotch developed in nonsprayed plots. In cases where less than 30% disease developed in nonsprayed plots, all data points were clustered in the low range of disease severity, and the slopes of regression lines were not significantly different from zero (*data not shown*).

The fungicide treatments caused a range of values for leaf rust and leaf blotch severities, yield, and test weight among the 32 plots of each of the reported cultivar–location–year combinations. There were significant ($P \leq 0.002$ in all cases) positive relationships between percent yield loss and leaf rust severity, and between percent test weight loss and leaf rust severity on Florida 302 and Rosen (Fig. 1, Table 2). Except for Rosen at Kibler in 1991, which had quadratic relationships of yield and test weight loss to leaf rust severity, plots of residuals for the linear regressions showed no systematic pattern indicative of lack of fit.

For Florida 302, there were no significant differences ($P = 0.05$) among slopes for yield loss caused by leaf rust (Table 2). The slope for test weight loss caused by leaf rust was significantly greater at Kibler in 1991 than in the other environments.

For Rosen, there were no significant differences among the three constant slopes for yield or test weight losses caused by leaf rust. The slopes for yield and test weight losses at Kibler in 1991 depended on leaf rust severity and were not statistically compared to the other slopes that were independent of leaf rust severity.

There were significant ($P \leq 0.002$ in all cases) positive relationships between percent yield loss and Septoria leaf blotch severity, and between percent test weight loss and Septoria leaf blotch severity on Florida 302, Rosen, and Cald-

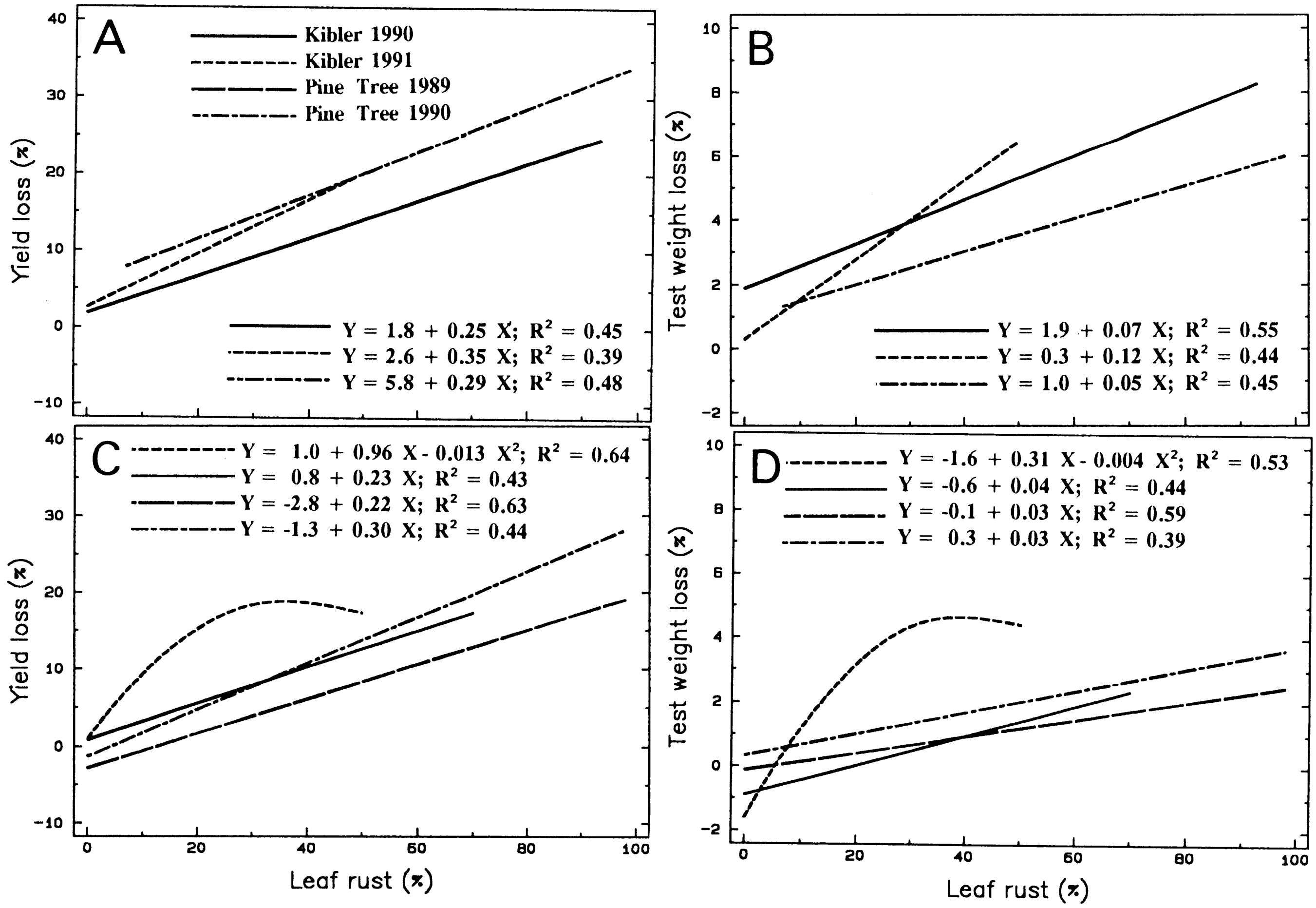

Fig. 1. Relationship of yield loss or test weight loss to leaf rust severity on wheat cultivars Florida 302 and Rosen. **(A)** Yield loss on Florida 302. **(B)** Test weight loss on Florida 302. **(C)** Yield loss on Rosen. **(D)** Test weight loss on Rosen.

well (Fig. 2, Table 2). Intercepts were negative, except for percent yield loss on Caldwell at Pine Tree in 1989. Multiple linear regressions of both leaf rust and leaf blotch severities on yield and test weight loss found both independent variables to be significant in only one cultivar–location–year combination (*data not shown*).

For Florida 302, there were no significant differences among slopes for yield or test weight losses due to leaf blotch (Table 2). For Rosen, the slope for yield loss was significantly greater at Pine Tree in 1989 than in 1990. For Caldwell, there were no significant differences among slopes for either yield or test weight losses. An examination of plots of residuals versus leaf blotch severity revealed no systematic pattern indicative of lack of fit.

Similar experiments were initiated at Kibler in 1989 and at Pine Tree in 1991, but they were not included in this report. There were drought conditions at Kibler during the spring of 1989, and no diseases developed. Large portions of the plot were killed by standing water at Pine Tree in 1991, and the test was abandoned.

Table 2. Slopes for percent yield loss and percent test weight loss regressed individually versus leaf rust and Septoria leaf blotch severities

			Slope[w]			
			Leaf rust[x]		Septoria leaf blotch[x]	
Cultivar	Location	Year	Yield loss	Test weight loss	Yield loss	Test weight loss
Florida 302	Kibler	1990	0.25 a	0.07 a	...	...
		1991	0.35 a	0.12 b	...	...
	Pine Tree	1989	...[y]	...	0.41 a	0.03 a
		1990	0.29 a	0.05 a	0.44 a	0.07 a
Rosen	Kibler	1990	0.23 a	0.04 a	...	...
		1991	0.96-0.026X[z]	0.31-0.008X[z]	...	...
	Pine Tree	1989	0.22 a	0.03 a	0.60 b	0.07 a
		1990	0.30 a	0.03 a	0.34 a	0.04 a
Caldwell	Kibler	1990	...	...	0.43 a	0.06 a
		1991	...	...	0.27 a	0.07 a
	Pine Tree	1989	...	...	0.26 a	0.06 a

[w] All slopes were significantly different from zero ($P \leq 0.002$).
[x] Slopes within a cultivar and column followed by the same letter are not significantly different using two sample *t* tests ($P = 0.05$).
[y] Disease severity greater than 30% did not develop, and data were not analyzed.
[z] The slope depended on the leaf rust severity (X) and was not statistically compared to the other slopes that were independent of leaf rust severity.

DISCUSSION

Rates of yield loss due to leaf rust were similar on Florida 302 and Rosen. Average rates of yield loss were 0.30 and 0.25% for each 1% increase in leaf rust severity on Florida 302 and Rosen, respectively (Fig. 1, Table 2). The higher rate of test weight loss on Florida 302 at Kibler in 1991 may have been caused by the earlier development of leaf rust (Table 1). The average rate of test weight loss on Florida 302 (0.08%) was more than double the rate on Rosen (0.03%). The quadratic relationship of leaf rust severity to yield and test weight loss on Rosen at Kibler in 1991 probably was caused by most of the data points being in the low range of leaf rust severity and only a few points (from the nonsprayed and Latron CS-7 checks) in the 30–50%

range. When data for the checks were eliminated from the analyses, the slopes were not significantly different from zero (*data not shown*).

Rates of yield loss due to Septoria leaf blotch averaged 0.43, 0.47, and 0.32% for each 1% increase in leaf blotch severity on Florida 302, Rosen, and Caldwell, respectively (Fig. 2, Table 2). The higher rate of yield loss on Rosen at Pine Tree in 1989 may have been caused by the earlier development of leaf blotch (Table 1). Average rates of test weight loss due to leaf blotch were similar on Florida 302 (0.05%), Rosen (0.06%), and Caldwell (0.06%). Intercepts for regressions with leaf blotch severity as the independent variable generally had negative intercepts (Fig. 2). This probably was caused by the inability to attain complete control of leaf blotch even with the best fungicide treatment (3; *data not shown*).

Data reported here are the first published estimates for rates of yield and test weight losses caused by leaf rust and leaf blotch of wheat in Arkansas, and they document the importance of these diseases as constraints to profitable wheat production. Subba Rao et al (12) found linear relationships between yield loss and leaf rust area under the disease progress curve (AUDPC) for wheat cultivars McNair 1003 and Coker 762 in Louisiana. Maximum predicted yield losses were approximately 35 and 27% for McNair 1003 and Coker 762, respectively. Seck et al (10) estimated yield losses of four isogenic wheat lines to be 21–38% under natural epidemics, depending on the line. Eyal and Ziv (4) reported yield losses of 20–40% for Septoria leaf blotch. These yield losses were comparable to the maximum predicted yield losses in this study (Figs. 1 and 2).

Estimates of yield and test weight losses caused by leaf rust or leaf blotch individually were complicated by the presence of both diseases. When losses are caused by more than one disease, loss estimates based on more than one single-disease model will likely overestimate or

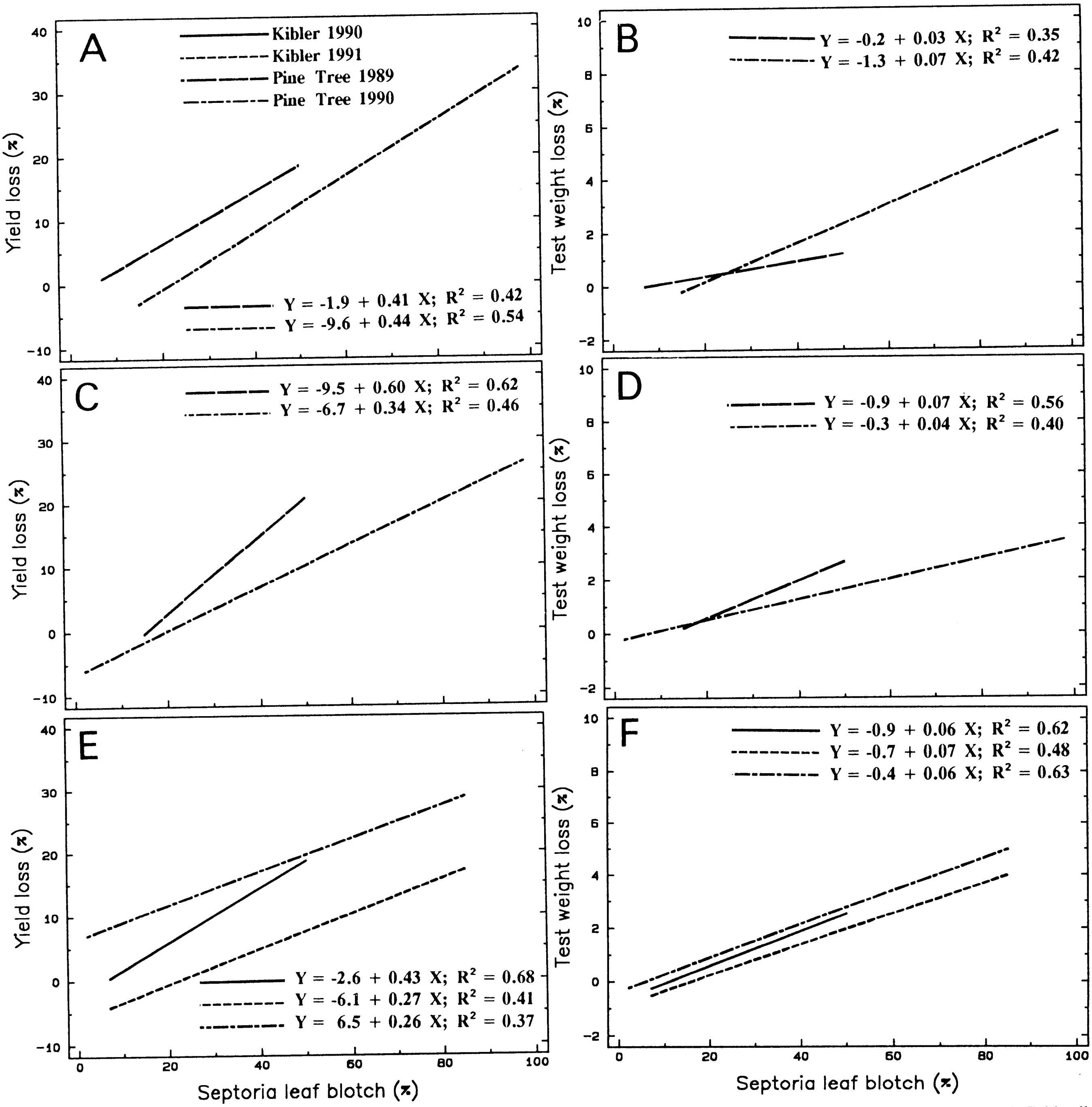

Fig. 2. Relationship of yield loss or test weight loss to Septoria leaf blotch severity on wheat cultivars Florida 302, Rosen, and Caldwell. **(A)** Yield loss on Florida 302. **(B)** Test weight loss on Florida 302. **(C)** Yield loss on Rosen. **(D)** Test weight loss on Rosen. **(E)** Yield loss on Caldwell. **(F)** Test weight loss on Caldwell.

underestimate the total loss (13). Attempts were made to estimate losses based on both leaf rust and leaf blotch severities using multiple linear regression, but adding a second disease variable did not improve the estimates. The second disease variable usually had a nonsignificant effect on the relationship. This probably was due to the positive correlation between leaf rust and leaf blotch severities ($r = 0.50$–0.92, depending on the cultivar, location, and year). Although leaf blotch always developed earlier in the season than leaf rust, both diseases usually increased over time; and this caused the two severity measurements to be correlated. Multiple regressions involving correlated variables are expected to be nonsignificant (8). This complication was not a factor in determining yield losses caused by powdery mildew and leaf rust in North Carolina, because powdery mildew developed from the seedling stage until about flag leaf emergence and then declined, whereas leaf rust epidemics generally began about flag leaf emergence and continued through the end of the season (2). The percentage of total foliage diseased may have been a better predictor of losses from both leaf rust and leaf blotch.

Disease severity at soft dough stage explained 37–68% of the yield losses and 39–63% of test weight losses caused by leaf rust or leaf blotch (Figs. 1 and 2). Higher coefficients of determination (r^2) probably could have been obtained if several evaluations of disease severity had been made and severities were expressed as AUDPC. Data expressed as AUDPC may have allowed estimates of crop losses at low-to-intermediate levels of final disease severity that could not be made or had poor fits to the regression line in this study.

Results of this study support the use of foliar fungicides on wheat in Arkansas to control leaf rust and leaf blotch, and to protect yield and test weight potential. Estimates of rates of yield and test weight losses should be useful for making disease management decisions.

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