Disease Control and Pest Management

Influence of Winter Wheat Management Practices on the Severity of Powdery Mildew and Septoria Blotch in Pennsylvania

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ABSTRACT

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Effects of row spacing, seeding depth, seeding rate, and spring nitrogen fertilization level on the severity of powdery mildew (caused by *Erysiphe graminis*) and Septoria blotch (caused by *Leptosphaeria nodorum*) on winter wheat were evaluated. Experiments were conducted on 13 farms located in Centre County and Lancaster County, PA, during the 1981 and 1982 growing seasons. Management variables tested were two planting depths (2 and 4 cm), two row spacings (13 and 18 cm), three seeding rates (101, 168, and 235 kg/ha), and four spring nitrogen levels (0, 34, 67, and 101 kg/ha). The management practices evaluated did not consistently interact to influence the severity of either disease, indicating that the effects of any single management practice could be considered individually. As the level of spring nitrogen fertilizer was increased, the severity of powdery mildew and Septoria blotch increased significantly. Powdery mildew severity tended to be higher at the wide row spacing and lowest seeding rate. Increasing seeding rate significantly increased Septoria blotch severity in four tests and significantly decreased it in another. Seeding depth did not consistently influence the severity of either disease.

Powdery mildew (*Erysiphe graminis* DC. f. sp. *tritici* E. Marchal) and Septoria blotch (*Leptosphaeria nodorum* Muller) are the most important foliar diseases of winter wheat (*Triticum aestivum* L.) in the mid-Atlantic states. Although chemicals are available that can control these diseases, their use is not always economic or completely effective. Changing crop management practices may be another way to reduce the severity of these diseases.

The incidence and severity of mildew is influenced to a great extent by the timing and amount of nitrogen fertilizer. High levels of nitrogen (N), for example, increase the severity of powdery mildew (6,7,13,14,22,25).

Johnston et al (11) reported that high levels of N fertilizer decreased the severity of Septoria blotch but this is contradicted by the results of other studies (23,28). Pirson (18) and Bockmann (3) found that increased N fertilization and applications of chlorocholinechloride, respectively, delayed maturation of wheat, and thereby increased the risk of infection by the leaf and glume blotch fungi.

Bockmann (2) indicated that the most decisive influence on Septoria blotch is the microclimate. Pycnidiospores of *L. nodorum* require the presence of free water for release and can then be dispersed by rain splash (20). Therefore, dense seeding of wheat, narrow row spacing, or both, may significantly alter the crop microclimate or modify canopy architecture in such a way as to affect the movement of inoculum and, hence, the severity of Septoria blotch.

Jenkyn (10) presented no data but stated that he observed more mildew in wheat planted at 25 cm row spacings than in rows spaced 13 or 18 cm apart, while Shaner (21) found no consistent row

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spacing effect on the disease. Last (15) reported no differences in the incidence of powdery mildew or its effect on yield when he increased the seeding rate of barley from 101 to 168 kg/ha. However, other researchers (8,16,25) have indicated that dense seeding of cereals may increase the risk of infection by *E. graminis*.

Much of the previous research has focused on the effects of individual crop management practices in relation to foliar diseases and results are often contradictory.

We feel it is important to determine if management variables interact to affect the severity of disease, as well as what the effects of the individual practices are. The purpose of this study was to evaluate the influence of row spacing, seeding depth, seeding rate, spring N fertilization, and possible interactions of these factors on the severity of the foliar diseases caused in wheat by *E. graminis* and *L. nodorum*.

MATERIALS AND METHODS

Field experiments were conducted during 1981 and 1982 on farms in Centre and Lancaster counties, in central and southeastern Pennsylvania, respectively. The location and crop history of each field for both years will be referred to by the corresponding experiment code: L = Lancaster County, C = Centre County, 81 = 1981, 82 = 1982, w = wheat, c = corn, o = oats, t = tobacco, s = soybean, and a = alfalfa. The two counties and various cropping sequences were included to observe the influence of gross climatic differences and previous crop on disease levels and the treatment effects. The winters in Lancaster County are considerably shorter and milder than those experienced in Centre County. All wheat crops in Centre County were planted from 25 September to 1 October. In Lancaster County, experimental plots were planted between 6 and 9 October, except in the wheat-following-soybeans experiments, which were planted approximately 3 wk later in both years.

The factors and levels of each factor evaluated in this experiment were: two planting depths (2 and 4 cm), two row spacings (13 and 18 cm), three seeding rates (101, 168, and 235 kg/ha), and four spring nitrogen levels (0, 34, 67, and 101 kg/ha). A complete factorial treatment arrangement was employed within a randomized complete block design, replicated three times in each experiment, except at L81t, which was replicated only twice. All fields were tilled with a moldboard plow, except L81s, which was worked with a heavy disk. Twenty-two kilograms of actual N per hectare was applied in the fall at all locations and incorporated during secondary tillage operations. Limestone, phosphorus, and potassium were incorporated prior to planting according to soil test recommendations. The soft red winter wheat cultivar Roland (CI 17716) was planted in all experiments with a tractor-mounted drill (H & N Equipment, Colwich, KS), which was custom built to permit row-spacing adjustment and precise control of seeding rate and depth. Individual plots were 1.5 m wide and 14.6 m long. At the earliest opportunity in the spring, N, in the form of ammonium nitrate, was applied to individual plots with a 1.5-m wide hand-pulled spreader.

The severity of powdery mildew and Septoria blotch was visually assessed according to the disease assessment procedures devised by James (9). The top two (in 1981) or three (in 1982) leaves of 10 tillers, selected at random throughout each plot, were evaluated individually for the percentage of leaf area covered with sporulating colonies of *E. graminis* or necrotic lesions caused by *L. nodorum*. Since *L. nodorum* and *Mycosphaerella graminicola* (Fuckel) Schroeter produce similar foliar symptoms and positive differentiation between the two pathogens can only be accomplished by microscopic examination of pycnidiospores (24), no attempt was made to distinguish between them. However, *L. nodorum* is generally the primary pathogen responsible for Septoria blotch in Pennsylvania. Severity values for each leaf position for each disease were averaged over the 10 tillers. Means for each leaf position were totaled rather than averaged to provide the severity values used in statistical analysis because of differences in evaluation procedures between years and variations in disease severity between the leaf positions. Plants were evaluated at growth stage 10.5 (spike fully extended) of the Feekes scale (12) in 1981 and 10.2 (spike one-quarter extended) in 1982. Less senescence of lower leaves in 1982 allowed us to evaluate the severity on the top three leaves. Since in 1981 and 1982, severity values were derived from the sum of the top two and three leaves, respectively, no attempt was made to compare values between years. Data for disease severity at individual locations were subjected to analysis of variance with sums of squares partitioned into single-degree-of-freedom contrasts (26).

RESULTS

Row spacing. Effects of row spacing significantly influenced the severity of powdery mildew at C81a and L82c (Table 1). In both instances, there was more disease in plots with rows spaced 18 cm apart than in those with rows spaced 13 cm apart. Though not statistically significant, a similar trend was observed in nine of the 11 other experiments.

Row spacing did not consistently affect the severity of Septoria blotch (Table 2), although in two experiments (L82w and L82t) there was significantly more Septoria blotch at the wider row spacing.

Planting depth. Planting depth significantly affected mildew at only two locations (Table 1). At L81s, mildew was most severe when seeds were planted 4 cm deep, but at L82t it was most severe when seeds were planted 2 cm deep. Deeper seed placement significantly reduced Septoria blotch severity at C81c.

Seeding rate. A significant inverse relationship between powdery mildew severity and rate of seeding occurred at three locations (Table 1). Reduction in disease as seeding rate increased was linear at C81a and L82w. A significant quadratic response to seeding rate occurred at C82w, with disease severity lowest at the 168 kg/ha rate. At most locations where the effect of seeding rate was not significant, highest severity values occurred at the 101 kg/ha rate.

Seeding rate influenced the severity of Septoria blotch at five of the 13 locations (Table 2). At C81a, L81t, L82c, and L82s, disease severity increased with seeding rate. These increases were linear in all experiments except L82c, where the response was quadratic, with least disease at the 168 kg/ha seeding rate. At C81o, there was an inverse relationship with least disease at 235 kg of seed per hectare. No trends were observed at the other eight locations.

Spring nitrogen fertilization. Linear increases in severity of powdery mildew with increasing levels of N occurred in all 1981 experiments (Table 1). In 1982, powdery mildew also was increased by the higher rates of N, but the form of response varied from linear to cubic (Table 1).

Septoria blotch severity was significantly influenced by N fertilization in all experiments except L81w (Table 2). The response curves usually were linear but quadratic and cubic responses also were observed. At all locations where N was a significant factor, except C82w, severity levels increased with N, and the highest values occurred at 67 or 101 kg N/ha. At C82w, there was a signficant quadratic decrease in Septoria blotch severity as N was increased with the greatest decrease occurring between 0 and 34 kg N/ha.

Interactions. With respect to powdery mildew, significant interactions between treatments were observed at only four of the 13 locations. Although interactions affecting Septoria blotch were observed more frequently, none occurred consistently across locations. Even specific interactions occurring at more than one location were dissimilar and inexplicable. Due to the infrequency and inconsistency of occurrence, data on interaction effects on powdery mildew and Septoria blotch are not presented.

DISCUSSION

The severity of Septoria blotch increased significantly when additional increments of spring N were applied. Shaner et al (23) and Vos (28) made similar observations in research not directly testing this relationship. Fellows (4) studied the effect of fertility on infection of wheat by *S. tritici* in the greenhouse and showed that plants fertilized 7–13 days prior to inoculation had higher levels of infection than plants that received no fertilizer. He also noted that the most vigorous plants in the field tended to sustain more infection by *S. tritici*. A report by Johnston et al (11) is the only one that contradicts our findings. They observed an inverse relationship between N level and Septoria blotch on spring wheat with treatments of 80 kg N/ha at planting plus 0, 40, or 80 kg N/ha prior to growth stage 5 (leaf sheaths erect). Total N available to the plants in that study probably was considerably higher and Septoria blotch severity values were consistently well above those in our experiments. Although we did observe such an inverse relationship in one of our experiments (C82w), we feel confident that the severity of Septoria blotch will generally increase as more spring N is applied to wheat grown in Pennsylvania.

In all of our experiments, powdery mildew severities increased significantly as the level of N applied in the spring increased. These results support those of other researchers (7,13,14,22,25). Although our experiments were not designed to determine why treatments influenced the severity of powdery mildew, we believe the response

TABLE 1. Effect of row spacing, seeding depth, seeding rate, and spring N-fertilization level on powdery mildew severity on winter wheat in Pennsylvania in 1981 and 1982

	Powdery mildew severity[a] at:														
Variable	C81w[b]	C81c	C81o	C81a	L81w	L81c	L81s	L81t	$\bar{x}$(1981)	C82w	L82c	L82w	L82s	L82t	$\bar{x}$(1982)
Row spacing (cm)															
13	1.0	5.4	3.6	5.6	2.1	4.6	7.7	8.3	4.8	6.0	10.3	7.5	6.6	10.2	8.1
18	1.0	4.8	4.0	6.4	2.4	4.7	8.5	7.9	5.0	6.2	11.2	8.0	7.1	10.3	8.6
Contrast[c]	NS	NS	NS	L	NS	NS	NS	NS		NS	L	NS	NS	NS	
Seeding depth (cm)															
2	1.0	5.0	3.9	6.1	2.2	4.4	7.4	7.6	4.7	5.9	10.8	7.8	7.1	10.7	8.4
4	1.0	5.2	3.7	5.9	2.3	5.0	8.8	8.5	5.0	6.3	10.8	7.7	6.6	9.7	8.2
Contrast	NS	NS	NS	NS	NS	NS	L	NS		NS	NS	NS	NS	L	
Seeding rate (kg/ha)															
101	1.1	5.6	3.4	6.6	2.4	4.9	8.3	8.5	5.1	6.6	11.2	8.3	7.3	10.2	8.7
168	1.1	4.9	4.0	5.7	2.3	4.3	7.6	8.1	4.8	5.7	10.2	7.5	6.5	10.7	8.1
235	0.8	4.8	4.0	5.7	2.1	4.8	8.3	7.6	4.8	6.0	10.9	7.4	6.7	9.8	8.2
Contrast	NS	NS	NS	L	NS	NS	NS	NS		Q	NS	L	NS	NS	
Spring N level (kg/ha)															
0	0.3	2.5	1.8	4.5	1.5	2.6	6.3	4.4	3.0	3.4	6.9	5.3	4.1	7.3	5.4
34	1.0	4.4	3.2	6.0	2.0	4.0	7.6	5.7	4.2	5.7	9.1	6.8	6.0	9.2	7.4
67	1.2	6.2	4.8	6.6	2.4	5.6	8.9	9.2	5.6	6.5	11.6	7.9	7.2	10.2	8.7
101	1.6	7.3	5.5	6.9	3.1	6.3	9.5	12.9	6.6	8.8	15.5	10.9	10.0	14.2	11.9
Contrast	L	L	L	L	L	L	L	L		C	L	Q	L	Q	
$\bar{x}$	1.0	5.1	3.8	6.0	2.3	4.7	8.1	8.1		6.1	10.8	7.7	6.8	10.2	

[a] Values are the mean sum of percent disease severity on the top two and three leaves in 1981 and 1982, respectively, over all treatment combinations.
[b] Experiment code: L = Lancaster County, C = Centre County, 81 = 1981, 82 = 1982, w = wheat, c = corn, o = oats, a = alfalfa, s = soybeans, and t = tobacco (crops refer to crop preceding wheat).
[c] Orthogonal contrasts significant ($P = 0.05$) for the main effect (L = linear, Q = quadratic, C = cubic, and NS = nonsignificant).

TABLE 2. Effect of row spacing, seeding depth, seeding rate, and spring N-fertilization level on Septoria blotch severity on winter wheat in Pennsylvania in 1981 and 1982

	Septoria blotch severity[a]:														
Variable	C81w[b]	C81c	C81o	C81a	L81w	L81c	L81s	L81t	$\bar{x}$(1981)	C82w	L82c	L82w	L82s	L82t	$\bar{x}$(1982)
Row spacing (cm)															
13	23.7	30.0	28.4	2.6	4.8	6.6	4.5	6.6	13.4	12.0	8.7	5.4	3.0	7.0	7.2
18	24.8	32.2	28.7	2.9	4.7	6.6	4.9	6.0	13.8	11.1	8.9	6.3	3.2	8.3	7.5
Contrast[c]	NS	NS	NS	NS	NS	NS	NS	NS		NS	NS	L	NS	L	
Seeding depth (cm)															
2	22.6	33.0	29.2	2.6	4.4	6.7	4.8	6.0	13.6	12.1	9.1	6.0	2.9	7.8	7.6
4	25.9	29.2	27.9	2.9	5.2	6.4	4.5	6.7	13.6	11.0	8.6	5.7	3.2	7.5	7.2
Contrast	NS	L	NS	NS	NS	NS	NS	NS		NS	NS	NS	NS	NS	
Seeding rate (kg/ha)															
101	24.9	31.0	31.8	2.2	5.2	6.1	4.7	5.3	13.9	11.3	8.2	5.8	2.5	7.0	6.9
168	24.5	32.8	27.6	2.9	4.9	6.2	4.2	6.4	13.7	10.1	8.0	6.0	3.2	8.0	7.0
235	23.5	29.5	26.2	3.1	4.2	7.4	5.1	7.4	13.3	13.2	10.3	5.9	3.5	8.0	8.2
Contrast	NS	NS	Q	L	NS	NS	NS	L		NS	Q	NS	L	NS	
Spring N level (kg/ha)															
0	17.0	31.0	25.0	2.0	4.6	3.8	3.2	4.5	11.4	18.2	7.8	4.8	2.1	5.8	7.8
34	23.3	32.5	29.8	2.7	4.3	6.5	4.2	5.5	13.6	11.0	7.9	5.4	2.6	7.6	6.9
67	25.4	27.0	28.4	3.1	4.8	7.7	6.3	8.2	13.8	8.7	9.4	5.9	3.5	8.5	7.2
101	31.3	34.0	31.0	3.2	5.4	8.2	5.1	7.3	15.7	8.3	10.2	7.3	4.0	8.7	7.7
Contrast	L	C	L	L	NS	Q	C	L		Q	L	L	L	L	
$\bar{x}$	24.3	31.1	28.5	2.8	4.8	6.6	4.7	6.3		11.5	8.8	5.9	3.1	7.6	

[a] Values are the mean sum of percent disease severity on the top two and three leaves in 1981 and 1982, respectively, over all treatment combinations.
[b] Experiment code: L = Lancaster County, C = Centre County, 81 = 1981, 82 = 1982, w = wheat, c = corn, o = oats, a = alfalfa, s = soybeans, and t = tobacco (crops refer to crop preceding wheat).
[c] Orthogonal contrasts significant ($P = 0.05$) for the main effect (L = linear, Q = quadratic, C = cubic, and NS = nonsignificant).

was in some way related to the nutritional or physiological status of the wheat plant. Tapke (27) proposed that the interaction of all factors involved in plant growth affect predisposition to powdery mildew. Last (13,14) related the amount of disease to the relative growth rate of the leaves and showed that application of N increased leaf growth rate. Since *E. graminis* is an obligate parasite, conditions that favor the growth of the host plant (e.g., sufficient N) may in turn favor growth and development of the parasite. Shaner and Finney (22) have also hypothesized that factors such as soil N may affect the host and influence the reproduction of *E. graminis*. In work with barley, Bainbridge (1) demonstrated that infection, pustule expansion, and sporulation of *E. graminis* increased when plants received higher levels of N. Similar effects could have resulted in the higher levels of disease severity we observed as spring N fertilization level was increased on wheat.

Additional evidence that more vigorous plant growth is related to increased powdery mildew severity may be provided by the effects of row spacing and seeding rate on the disease. Although not always statistically significant, powdery mildew tended to be more severe at the wider row spacing and at the lowest seeding rate. This is contradictory to most other reports (8,21,25) of higher mildew severity when plants are seeded more densely. However, Shaner (21) did find more mildew on the cultivar Vermillion when grown in widely spaced rows and our observations concur with those of Jenkyn (10). Changes in plant population density may decrease interplant competition for light, water, and nutrients. As a result, plants may grow more vigorously and incur higher powdery mildew severity in a response similar to that which develops under high N fertility. Changes in microclimate associated with certain plant densities and crop canopies also may have contributed to these trends.

Septoria blotch severity was positively associated with seeding rate at four of the five locations where significant responses occurred. Significant increases in tiller number with higher seeding rates were observed in these experiments (5) and could have favored spore deposition or microclimatic conditions that led to such results. However, since disease significantly increased in only four of the 13 experiments and decreased in another, we feel that broad generalization based on these results is not warranted. Further work on this relationship is needed to determine what risk would be incurred by increasing seeding rates.

Row spacing and seeding depth seldom affected the severity of Septoria blotch. Initially, we believed that closer row spacing might increase disease by aiding spread of the pycnidiospores. Consistent and significant yield increases were obtained at the closer row spacing (19) and it appears that growers could reduce row spacing from the customary 18 cm to at least 13 cm without suffering more infection by *L. nodorum*.

Previous crop or county did not alter the trends for the effects of treatments on either disease. Mean powdery mildew severities in experiments with wheat planted following either wheat or oats tended to be relatively lower than in those where other crops were followed (Table 1). This was unexpected because we believed that inoculum from previous wheat crop residue and volunteer wheat plants would cause powdery mildew severity to be higher than for other rotations. In Pennsylvania, corn and tobacco generally are fertilized with much higher levels of N than small grain crops and, since some of the N applied to those crops or fixed by legumes such as soybeans and alfalfa may be available the following season, we believe this could partially explain the observed differences in severity of powdery mildew. Because a reliable test is not available, N levels were not measured prior to planting our experiments. Parmentier and Rixhon (17) have related powdery mildew severity to the amount of N applied, organic N supplied by the preceding crop, and the amount of N mineralized prior to planting the wheat crop. They found mildew severities higher in wheat grown after beans and alfalfa compared to wheat grown after corn, oats, barley, and other crops.

Interactions between the crop management practices tested did not consistently influence the severity of powdery mildew or Septoria blotch. No one interaction was statistically significant in more than three of the 13 experiments conducted during the 2 yr. Interactions were not specific to the previous crop and tended to be distributed evenly between the two counties. For these reasons, we believe the statistically significant interactions were probably spurious or caused by environmental factors such as soil type, topography, or weather, which were specific to each location. Since interactions among management practices were infrequent, they probably are not important considerations when formulating general recommendations for Pennsylvania.

The disease severities presented in this report do not approach the maximum levels observed in Pennsylvania. However, they are representative of the average amounts of disease observed on cultivars of comparable resistance presently grown throughout the state. Therefore, our conclusions provide valuable information upon which crop and disease management recommendations for Pennsylvania can be based. Extrapolation of our results to other areas should be practiced with caution since environmental influences on disease development and treatment responses may be significant.

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