The Effect of Planting Date on Fall Infections and Epidemics of Powdery Mildew on Winter Wheat

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ABSTRACT

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The influence of planting date on fall and spring epidemics of powdery mildew was evaluated during 1982–1984 on the winter wheat cultivar Hart in field trials in Pennsylvania. The powdery mildew pathogen (*Erysiphe graminis* f. sp. *tritici*) infected wheat plants in the fall, but disease symptoms generally were not visible until spring. The incidence of fall infection decreased with later plantings. This fall infection could be prevented with a seed treatment of triadimenol fungicide. The reduction in fall infections led to reductions in disease severity the following spring, although 1 yr there were no differences in disease severities by the end of the spring season. However, the area under the disease progress curve reflected a reduction in the spring epidemic after reduced disease incidence in the fall for all 3 yr. The lowest grain yields were produced from the earliest fall plantings.

Cereals that are sown in autumn may be infected by various pathogens shortly after planting, and these infections may affect yield (2–4,7,8,13,14,17). The powdery mildew pathogen, *Erysiphe graminis* DC. f. sp. *tritici* Em. Marchal, may infect cereal plants in autumn (2,3,7, 8,10,12) and severe autumn epidemics may develop (3,12). The infection process has been well described (11), and the overwintering form of the pathogen has been identified as mycelium or conidia (8). The date of planting may have an impact on autumn infections of cereals (7,13,14,17). In studies directly involved with date of cereal planting and powdery mildew, earlier plantings resulted in more severe powdery mildew attacks (7,13). However, whereas several reports indicated that autumn epidemics affected yields (2,3,13), another report indicated that yields were unaffected (7).

Powdery mildew lesions generally are not visible on autumn-sown wheat in Pennsylvania (Frank, *unpublished*). This study was conducted to determine whether *E. g.* f. sp. *tritici* infects winter wheat after planting in Pennsylvania and if planting date has an effect on possible spring mildew epidemics.

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MATERIALS AND METHODS

Experiments were conducted on The Pennsylvania State University Research Farm near University Park in Centre County during 1981–1983. Henceforth, to avoid confusion between years in relation to fall and spring epidemics, the years will be designated as yr 1, yr 2, and yr 3. The plot area had been planted with corn in the 2 yr preceding the first year of these experiments. The recommended time for winter wheat planting in Centre County is 25 September–8 October (1). Planting dates were 21 September, 1 October, and 15 October in yr 1; 17 September, 1 October, and 15 October in yr 2; and 15 September, 30 September, and 13 October in yr 3. These dates and the disease rating dates were converted to their corresponding Julian date for statistical analysis. In yr 2 and yr 3, the plot areas were planted in a portion of the field comprising the oat buffer zones initially established in yr 1. This provided a rotation whereby wheat was always planted into soil that had not been planted with wheat for the past 3 yr.

The soft red winter wheat (*Triticum aestivum* L.) cultivar Hart was planted in all 3 yr. Plot design was unconventional but was selected to minimize interplot interference between planting data blocks and treatments. The design consisted of three large planting date blocks with eight replications within each block. A 30-m buffer area was planted with oats between each of the date blocks. Each planting date block consisted of two drill strips of eight plots per strip. Eight of the plots were planted with fungicide-treated seed (triadimenol 30% a.i., 77 ml/100 kg) to control early powdery mildew infections; the other eight plots did not receive this treatment. All wheat seed had been previously treated commercially with carboxin + thiram (17% + 17% a.i., 249 ml/kg); this combination has no effect on powdery mildew. The triadimenol-treated wheat also received a foliar application of triadimefon (50WP, 140 g/ha) at Feekes scale growth stage (GS) 6 (9). The two drill strips were separated from the other strips by a 7.2-m barley buffer. Each planting date block therefore consisted of eight untreated wheat plots and eight treated wheat plots. Each drill strip was 2.4 m wide and had nine rows, and each plot within the strip was 10.7 m long. Seeding depth, fall and spring fertilization, and spring herbicide rates used were recommended (1).

Since mildew lesions were not readily visible on the plants in yr 1 and yr 3, plants were removed from the field for evaluation on 11 November in yr 1 and on 16 November in yr 3. One linear meter of row was selected at random in each plot, and all plants in the meter were removed from the plot along with the soil. The plants were placed into flats along with additional soil and taken to a greenhouse where they were placed in a humidity chamber (approximately 85% RH, 12 hr daylength). After 72 hr, the plants were evaluated for the presence of powdery mildew by visual assessment. The number of powdery mildew lesions on each leaf of 25 randomly selected tillers was counted and recorded as the mean number of lesions per leaf. The number of leaves with mildew also was used to calculate mildew incidence for all leaves of a specific age in the 25-tiller sample. Only main tillers were used in this study. In order to make direct comparisons between leaves of a similar age in each planting date block, the topmost or youngest leaf was designated leaf 1.

In yr 2, powdery mildew was visible on the plants by 15 October, and because of the unusually warm weather, disease evaluations were made on 4 and 19 November, 10 December, and 14 January. The plants were collected as previously described. Because of the excessive number of lesions, however, the disease was measured as severity (percent leaf area infected) with the aid of a standard diagram (6). Twenty-five tillers were assessed in each replication, and a mean severity per tiller was calculated. The area under the disease progress curve (AUDPC) (16) was calculated for each planting date and treatment. In order to compare disease incidence in yr 2 with that in yr 1 and yr 3, the 19 November assessment data were used. All disease data were subjected to analysis of variance and mean separation using the Waller-Duncan *k*-ratio *t* test.

Because early planting may also influence the severity of barley yellow dwarf virus (BYDV), plant leaf tissue was removed from a linear meter of row in four of the replications. The tissue from one replication was mixed, and eight 3-g samples were finely chopped and placed into individual test tubes. The tubes were frozen and transported to W. F. Rochow at Cornell University, where they were analyzed for the presence of four characterized BYDV isolates (15).

A group of plants was selected from nonplot areas of the field in yr 1 in order to identify the overwintering stage of the pathogen. One set of leaves was examined under the microscope with incident light illumination. Another set of leaves was cut into 1-cm-long sections, stained with acid fuchsin in lactophenol, and examined under a phase-contrast microscope.

In the spring, the flag leaf and the leaf below were evaluated at three growth stages for powdery mildew severity. The assessments were made at GS-9, GS-10.1, and GS-10.54 each year. Severity was assessed by estimating the percentage of leaf area infected on the two leaves on 20 tillers selected at random in each plot, using a standard area diagram (6). The severity values for the two leaves were averaged to provide severity per tiller. The severity per plot was the mean of the severities for the 20 tillers, and this value was used in statistical analysis and in calculating an AUDPC for spring epidemics.

When plants were mature, plots were harvested with a combine and yields were calculated after adjustment to 13% moisture. The data for the 3 yr were combined and analyzed as a split plot in time and space.

RESULTS

The weather in the fall growing seasons of yr 1 and yr 3 was average for Centre County, Pennsylvania, and powdery mildew was not visible on the foliage of wheat plants in either year. When the plants were removed from the field and placed in a humidity chamber, however, the pathogen that was present on the leaves began to grow, and sporulating lesions were visible after 5 days. Microscopic examination of the leaf tissue indicated sparse mycelial growth scattered across the leaf surface. When tissues were stained, it was evident that the pathogen had penetrated the leaf surface, initiated haustorial formation, and developed a sparse mycelial mat on the leaf surface above the invaded cell. In a few instances, conidial chains were detected in the mycelial mat area. Although the disease was not evident to the naked eye, the pathogen was present and had colonized the leaf. In yr 1 and yr 3, the seed treatment provided complete fall mildew control, based on the incidence data in Table 1.

In the fall of yr 2, the symptoms of powdery mildew were evident in the test plots and in wheat fields across Centre County by 19 November. The temperatures were above normal from September through January. The disease continued to develop throughout the fall growing season and into the winter. Under these conditions, powdery mildew symptoms developed on plants from triadimenol-treated seed. The disease severity values for the fall assessment periods are presented in Figure 1. The greatest severities developed on plants that had been planted at the earliest date, while the severities on plants from the late planting were the lowest. Although powdery mildew did develop on the fungicide-treated plants, the severities were lower than on the nontreated plants. Triadimenol seed treatment also significantly reduced disease incidence (Table 1).

The aphid populations were extremely low in yr 1 and yr 3, and BYDV was not detected in the plant samples, based on enzyme-linked immunosorbent assay. In yr 2, only two samples from the earliest planting date block were positive for BYDV. The samples appeared to be infected with an isolate similar to the RMV-NY isolate (15). The only other disease that was evident on the test plants was Septoria nodorum leaf and glume blotch (*Leptosphaeria nodorum* Müller); this disease was confined to the two lowest leaves of the plants in all 3 yr, however, and the glume blotch phase of the disease was not evident.

In the spring of yr 1 and yr 3, powdery mildew was not detected on the foliage of fungicide-treated plants until GS-10.1 (Table 1). At this stage, treated plants had the foliar application of triadimefon as well as the triadimenol seed treatment. Mildew epidemics developed at a slower rate when plants were treated with fungicides, based on AUDPC values.

Table 1. Effect of fall planting date and fungicide treatment on fall incidence and spring severity of powdery mildew on the winter wheat cultivar Hart in Pennsylvania, 1982–1984

Planting date	Fungicide treatment[u]	Fall disease incidence[v] (%)	Spring disease severity[w] (%) at: GS-9	GS-10.1	GS-10.54	AUDPC[x]	Yield (kg/plot)
1981–1982							
21 September	T	0.0 a[y]	0.0 a	0.1 a	0.3 a	2 a	7.0 a
1 October	T	0.0 a	0.0 a	0.0 b	0.2 a	2 a	7.7 b
15 October	T	0.0 a	0.0 a	0.0 b	0.2 a	2 a	7.5 b
21 September	NT	60.8 a	3.1 a	4.2 a	6.2 a	127 a	5.0 a
1 October	NT	13.2 b	0.8 b	2.1 b	5.9 a	82 b	7.9 b
15 October	NT	6.7 c	0.1 c	1.4 c	5.8 a	67 c	7.3 b
Significance[z]		*	*	*	*	*	*
1982–1983							
17 September	T	1.0 a	0.1 a	1.7 a	7.7 a	98 a	7.5 a
1 October	T	0.0 b	0.0 b	1.0 b	6.5 b	75 b	8.6 b
15 October	T	0.0 b	0.0 b	0.8 c	4.8 c	55 c	9.2 c
17 September	NT	31.2 a	4.3 a	7.7 a	9.6 a	245 a	7.1 a
1 October	NT	5.6 b	2.1 b	5.8 b	7.0 b	174 b	6.9 a
15 October	NT	0.4 c	0.9 c	3.9 c	6.0 c	125 c	8.0 b
Significance		*	*	*	*	*	*
1983–1984							
15 September	T	0.0 a	0.0 a	0.6 a	2.3 a	22 a	4.7 a
30 September	T	0.0 a	0.0 a	0.2 b	1.6 b	13 b	6.6 c
13 October	T	0.0 a	0.0 a	0.0 c	1.3 c	8 c	5.9 b
15 September	NT	24.2 a	0.7 a	2.0 a	2.7 a	46 a	4.7 a
30 September	NT	5.5 b	0.1 b	0.9 b	2.3 b	25 b	6.2 c
13 October	NT	0.0 c	0.0 c	0.2 c	1.6 c	12 c	5.9 b
Significance		*	*	*	NS	*	NS

[u] Triademonal seed treatment (30% a.i., 77 ml/100 kg) plus a spring application of triadimefon foliar fungicide (50% a.i., 140 g/ha) at GS-6 (Feekes scale). T = treated, NT = not treated.
[v] Values are the means of all leaves on 25 tillers per replication, eight replications.
[w] Values are the means of 20 tillers per replication, eight replications.
[x] Area under the disease progress curve as calculated by Tooley and Grau in 1984 (16).
[y] Means in a column (for the three dates by treatment) followed by the same letter are not significantly different based on the Waller-Duncan *k*-ratio *t* test, $k = 100$.
[z] Significance of fungicide treatment compared with no treatment, based on ANOVA. The analysis is pooled over the three planting dates.

The only instance where the fungicide treatment did not significantly reduce powdery mildew severity was the final assessment in the spring of 1984.

With regard to fungicide-treated plants, the planting date had little effect on spring disease severity in yr 1. The only significant difference occurred at GS-10.1, but the disease pressure was very low (Table 1). The AUDPC for the season also was nonsignificant.

In the spring of yr 3, the first effect of planting on disease occurred at GS-10.1, but the difference remained through the next assessment and contributed to a significant AUDPC (Table 1). In all cases, the disease severities for the three dates could be separated from each other statistically, and the earliest planting had the greatest disease severity and AUDPC.

The spring of yr 2 was similar to that of yr 3 except that the overall disease severities were greater at each assessment period, the AUDPC was greater, and the disease was present at every assessment period on plants that were planted early.

With regard to nontreated plants, the severities for the three dates were significantly different from each other for all assessments made during the 3 yr, except for the final assessment in the spring of yr 1 (Table 1). In all cases, the greatest severity occurred on plants in the earliest planting and the lowest severity occurred on those in the late planting. The AUDPC was greatest for the earliest planting in all 3 yr.

Fungicide treatment increased yields in the first 2 yr of this study (Table 1). In yr 3, the fungicides had no effect and the yields were lower than in the previous year, even though disease pressure was relatively low when compared with yr 2.

In yr 1, the yields from the plants in the earliest planted plots were lower than those from the other plantings (Table 1). This occurred in both the treated and nontreated plots. In yr 3, results were similar for the treated and nontreated plots, with the lowest yield occurring in the earliest planting and the highest yield occurring in the second or recommended planting. Although the latest planting had yields below those for the second planting date, these yields were still higher than those for the earliest date.

In yr 2, the yields from the treated plots were the highest for all 3 yr of this study. The yields increased as the planting date was delayed. With the nontreated plots, the latest planting had higher yields than the other two plantings.

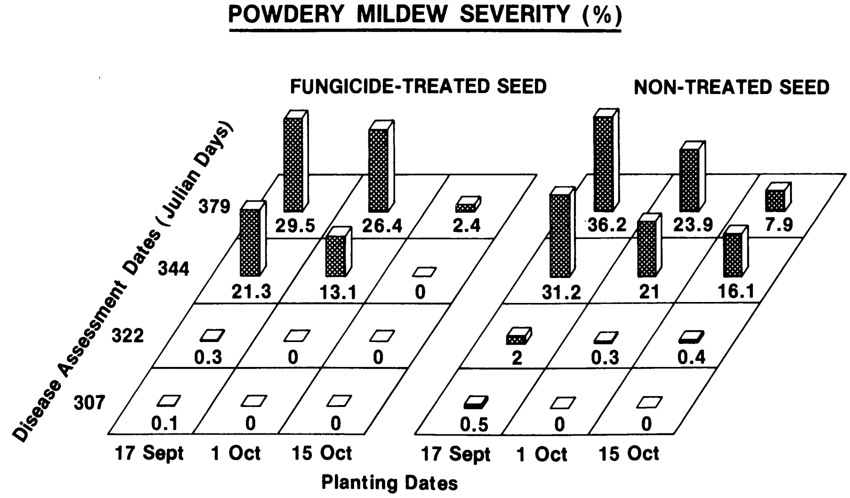

Fig. 1. The effect of triadimenol fungicide seed treatment and date of planting on powdery mildew epidemics in the fall of 1982 on the winter wheat cultivar Hart in Pennsylvania.

DISCUSSION

The powdery mildew pathogen, *E. g.* f. sp. *tritici*, infects winter wheat plants in Pennsylvania in the fall shortly after planting, but disease symptoms are generally not visible. The exception may occur in a season with an extended period of warm fall temperatures, as in 1982 (yr 2). Since that year, however, powdery mildew has not been visible on fall wheat plantings in Pennsylvania. Therefore, the pathogen infects plants in the fall and the inoculum is present for initiation of spring epidemics. These results support the findings of Brooks (2) and Finney and Hall (3), who emphasized the importance of fall infections. In Pennsylvania, this fall infection was never considered important because it was undetected.

It appears that seed treatment with triadimenol fungicide is a viable means of reducing these fall epidemics. Under average weather conditions, the pathogen would not establish itself in the fall-developed foliage, and the inoculum potential before spring would be nil. In some growing seasons, however, this reduction in initial inoculum would provide protection only until the pathogen was capable of establishing itself in the spring, and any yield benefits might be negligible (5). Therefore, a subsequent spring fungicide application may be warranted.

In the event that fungicide seed treatments might not be available, an adjustment in the date of fall planting could provide an alternative control mechanism. Over the 3 yr of this study, a planting date later than that recommended in *The Pennsylvania State Agronomy Guide* (1) reduced the incidence of powdery mildew in the fall and subsequently reduced the spring epidemic. This reduction was accomplished without the assistance of a fungicide for powdery mildew control.

Based on the cropping patterns of a specific grower, fungicide seed treatment and/or delayed planting may improve yield potential. Our study supported the reports by Brooks (2), Finney and Hall (3), and Prew et al (13) with severe fall epidemics contributing to yield reductions. Jenkyn (7) suggested that these epidemics did contribute to foliar damage but that plants compensated for this damage in the spring and yields were not affected. His fall epidemics were not severe, however, and his crop management practices favored additional spring tillering. This high input wheat production is not yet commonplace in the United States. Growers in Pennsylvania have continued to plant as early as possible in the fall in order to concentrate on the upcoming corn harvest. This study indicates that yields can be significantly reduced with this practice and that seed treatment can prevent some of this reduction. Based on previous disease records from specific areas of Pennsylvania, the combination of planting later in the recommended time frame plus seed treatment may provide the necessary ingredient for higher wheat yields.

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