# Effect of Triadimenol Seed Treatment on Powdery Mildew Epidemics on Winter Wheat

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## ABSTRACT

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Triadimenol seed treatment reduced powdery mildew disease severity on the winter wheat cultivar Hart in Pennsylvania in field experiments conducted in 1981–1983. Powdery mildew severity was assessed in the spring at four growth stages (GS-7, 9, 10.1, and 10.53, Feekes scale). In each year, and at all assessment periods, triadimenol generally reduced disease severity compared to the untreated controls. However, the yield of plots planted with triadimenol-treated seeds was increased only in 1982 and 1983. The area under the disease progress curve (AUDPC) provided a better estimation of the powdery mildew epidemic than the actual disease severity values or the apparent infection rates. Based on the AUDPC, the triadimenol seed treatment reduced disease severity in all 3 yr compared to untreated controls or seed treatments with either phenylmercury ammonium acetate or a carboxin-thiram combination. Triadimenol was the only seed treatment that contributed to an increase in yield.

Powdery mildew (*Erysiphe graminis* DC. f. sp. *tritici* E. Marchal) of wheat (*Triticum aestivum* L.) often has been controlled with resistant cultivars, but chemical control is important if resistant cultivars are not available (2,5). Chemical control of powdery mildew may be economically feasible in many growing seasons in the eastern United States.

The systemic foliar fungicide triadimefon (trade name, Bayleton) provided excellent powdery mildew control in Pennsylvania, especially when applied early in the growing season (1,16). Triadimenol (trade name, Baytan), a triazole derivative closely related to triadimefon, has been reported to control powdery mildew and increase yields of cereals when used as a seed treatment (3,10,13,15,19).

This study was conducted to investigate the effect of triadimenol seed treatment on powdery mildew epidemics on winter wheat and its subsequent effect on yield.

## MATERIALS AND METHODS

Field plots were established near University Park, PA, in soil that had been planted with forage grasses the previous 2 yr. Plots were planted on 22 September 1980, 29 September 1981, and 2 October 1982. The experiments will be identified by the year in which they were harvested, since the epidemics were evaluated in the spring following planting. The wheat cultivar Hart (CI 17426) was seeded at a rate of 167 kg/ha in rows spaced at 178 mm. Plots were fertilized with 672 kg/ha of 5-10-10 (N-P-K) just prior to planting.

In 1981, the seed treatments were: triadimenol (experimental formulation GUS 214B, 14% a.i. Gustafson Corp., Dallas, TX) at 81 and 162 ml/100 kg of seed; a commercial combination of carboxin (17% a.i.) and thiram (17% a.i.) (trade name Vitavax 200) at 249 ml/100 kg of seed; and phenylmercury ammonium acetate (PMAA) 3.5% a.i. at 56 ml/100 kg of seed. PMAA was one of the principle seed treatment fungicides used on wheat prior to 1970 and the carboxin-thiram combination is currently the most commonly used treatment. Seeds that had received one of these four treatments and an untreated control were planted in a randomized complete block design with four replications. The plot size was 0.9 m × 3.0 m, a 0.9-m alleyway was mowed between plots within a drill strip and drill strips were spaced 0.6 m. This experiment was duplicated in an adjacent location in the field and foliar fungicide sprays also were applied. Plots were topdressed with 67.2 kg/ha of $NH_4NO_3$ on 14 April 1981, 16 April 1982, and 4 April 1983.

Disease evaluations were initiated in 1981 at growth stage 7 (GS-7 on the Feekes scale) (11) on 20 tillers selected at random from each plot. Powdery mildew severity was assessed by estimating the percentage of leaf area infected on the leaf below the flag leaf (F-1) on each tiller using the procedures devised by James (7). This leaf was selected because it was available for infection throughout the entire assessment period. Values for the 20 tillers were totalled and a mean was calculated to represent powdery mildew severity for a particular plot. These assessments also were conducted at GS-9, 10.1, and 10.53. Septoria blotch (*Leptosphaeria nodorum* Muller) assessments also were made at these growth stages. In all 3 yr this disease was confined to the lower leaves (F-2 and F-3).

The duplicate set of plots was sprayed with the foliar fungicide triadimefon (11.5 ml a.i./ha) at GS-7 following disease assessment to control powdery mildew. This spray was applied to prevent interplot interference and to limit any yield differences that might develop to the effect of specific seed treatments prior to GS-7.

In 1982, the seed treatments were identical to those described for 1981, except that the triadimenol was applied only at 81 ml/100 kg of seed with the formulated product (Baytan 150 FS) provided by Mobay Corp., Kansas City, MO. The higher application rate of triadimenol was not used. The three seed treatments and a control were planted in a randomized complete block design with four replications. The plot size was 1.2 × 20 m and every other plot was planted with winter barley to reduce the interplot interference. Plots were fertilized and assessed for powdery mildew as described previously. Foliar fungicides were not applied to the 1982 experimental plots.

In 1983, the seed treatments were similar to those described in the 1982 experiment except that the carboxin-thiram treatment was excluded and an additional formulation of triadimenol was

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evaluated (triadimenol 30% a.i., trade name Baytan 30) at 77.8 ml/100 kg of seed. The design and procedures described for the 1982 experiment were used in 1983.

Percentage disease severities were converted to logits and the regression of logit on time was calculated (20). The slope of this regression line, which is an estimate of the apparent infection rate (*r* value), was calculated for each plot (20). As a second measurement of the disease epidemic, the area under the disease-progress curve (AUDPC) was calculated for each plot (18). The grain was harvested with a plot combine, and yields were adjusted to 13% moisture. Disease severities, *r* values, AUDPC, and yields were subjected to analysis of variance and mean separation (Waller-Duncan *k*-ratio *t*-test). Correlation coefficients were calculated for the variables AUDPC, *r*, and yield.

## RESULTS

In 1981, powdery mildew severity was significantly reduced by the triadimenol seed treatments compared to the untreated controls (Table 1). This reduction in severity was evident at each disease assessment period throughout the experiment and with both rates of triadimenol. Disease severity also was reduced at GS-9 and GS-10.1 by the PMAA treatments. The triadimenol treatments had the lowest final disease severity, the smallest AUDPC, and significantly higher *r* values compared to the other treatments. There appeared to be no difference in disease severity in plots treated with either the high or low rate of triadimenol, but there was a significant difference in the AUDPC and *r* values. There was no strong correlation between *r* value or AUDPC and yield.

In 1981, there were no yield differences between treatments. However, when the duplicate set of plots was sprayed with the foliar fungicide triadimefon at GS-7 to prevent interplot movement of the pathogen, there was a yield increase in the plots planted with triadimenol-treated (low rate) seeds compared to all other plots. Following the foliar fungicide application, powdery mildew was controlled completely in the duplicate plots, and disease symptoms were not visible in any plots through the final assessment period (GS-10.53).

A cool, wet spring in 1982 was more favorable for powdery mildew epidemics than in 1981, and disease severities were higher (Table 1). In 1982, powdery mildew severities were lower at GS-10.1 and 10.53 in all plots that had been planted with treated seed when compared to the control. The plots with the triadimenol seed treatment had lower disease severities at GS-9 through GS-10.53 and higher yields when compared to all other treatments. The triadimenol treatment again contributed to the lower AUDPC but the *r* value was not significantly different from those of the other treatments which is in contrast to the results for 1981. Both AUDPC (−0.92) and *r* value (−0.86) were correlated negatively to yield.

The fall of 1982 was extremely mild and there appeared to be good survival of *E. g.* f. sp. *tritici* based on the disease severities observed at GS-7 in 1983 (Table 1). While there was a difference between the triadimenol treatments and the other two treatments through the first two assessment periods, this difference was not apparent at GS-10.1. The mercury seed treatment was not effective in reducing powdery mildew severity in 1983. At the final assessment, the 30% a.i. triadimenol formulation appeared to be most effective in reducing powdery mildew severity and it provided the only yield increase over the control. However, the AUDPC and *r* values were similar for the two triadimenol formulations. AUDPC was again correlated negatively with yield (−0.88) but *r* value had a positive correlation (0.93).

In all three years, Septoria blotch severity was less than 5% on the third leaf (F-2) and 20% on the fourth leaf (F-3). Powdery mildew

TABLE 1. Effect of winter wheat seed treatments on severity of powdery mildew and subsequent yield in Pennsylvania, 1981-1983

| Treatment | Rate (ml/100 kg) | Disease severity[a] at: GS-7[b] | GS-9 | GS-10.1 | GS-10.53 | AUDPC[c] | $r$[d] | Yield (kg/ha) |
|---|---|---|---|---|---|---|---|---|
| 1981 | | | | | | | | |
| Triadimenol (14% a.i.) | 81 | 0.2 c | 0.7 d | 1.6 d | 2.6 b | 32.6 d | 0.21 a | 5,845 a |
| Triadimenol (14% a.i.) | 162 | 0.0 c | 1.0 cd | 2.3 c | 3.0 b | 43.9 c | 0.16 b | 5,683 a |
| PMAA[e] (3.5% a.i.) | 56 | 1.0 b | 1.3 c | 3.0 b | 3.8 a | 59.2 b | 0.06 c | 5,899 a |
| Carboxin + thiram (17% + 17% a.i.) | 249 | 1.6 a | 2.3 b | 3.8 a | 4.3 a | 78.5 a | 0.05 c | 5,887 a |
| Control | | 1.3 ab | 2.8 a | 3.7 a | 4.1 a | 79.3 a | 0.04 c | 5,737 a |
| 1982 | | | | | | | | |
| Triadimenol (15% a.i., FS) | 81 | 0.4 a | 0.8 c | 1.3 c | 2.1 c | 36.9 c | 0.05 a | 4,247 a |
| PMAA (3.5% a.i.) | 56 | 0.8 a | 2.4 b | 5.0 b | 6.2 b | 120.2 b | 0.07 a | 3,832 b |
| Carboxin + thiram (17% + 17% a.i.) | 249 | 0.8 a | 2.6 ab | 4.7 b | 6.0 b | 117.7 b | 0.09 a | 3,664 b |
| Control | | 1.0 a | 3.0 a | 6.1 a | 8.1 a | 150.7 a | 0.07 a | 3,730 b |
| 1983 | | | | | | | | |
| Triadimenol (15% a.i., FS) | 81 | 1.7 b | 2.3 b | 3.8 b | 5.5 b | 83.1 c | 0.05 ab | 3,664 a |
| Triadimenol (30% a.i.) | 77 | 1.0 c | 2.2 b | 3.7 b | 4.8 c | 76.7 c | 0.07 a | 4,019 b |
| PMAA (3.5% a.i.) | 56 | 2.5 a | 3.5 a | 4.3 ab | 5.8 ab | 101.8 b | 0.04 b | 3,604 a |
| Control | | 2.7 a | 3.6 a | 5.1 a | 6.3 a | 112.7 a | 0.04 b | 3,442 a |

[a]Severity assessed by estimating the percentage of leaf area infected on the leaf below the flag leaf by using the James scale. Values presented represent the mean of 80 leaves. Means in columns within a given year followed by the same letter are not significantly different ($P = 0.05$) (Waller-Duncan *k*-ratio *t*-test, $k = 100$).
[b]Growth stage according to the Feekes scale (11).
[c]Area under the disease progress curve (16).
[d]Apparent infection rate per day (19).
[e]Phenylmercury ammonium acetate.

severity averaged 30% on F-2 and was greater than 50% on F-3. There was a strong correlation between the powdery mildew severity on F-2 and the mean severity for the top three leaves (F, F-1, and F-2) in each of the 3 yr (0.92, 0.87, and 0.95 in 1981, 1982, and 1983, respectively). When plants reached GS-10.1, it was difficult to assess disease severity on F-3 accurately. There was no significant effect of seed treatment on Septoria blotch in any year.

## DISCUSSION

Triadimenol seed treatment effectively reduced the severity of powdery mildew epidemics in each year of this study. This reduction in disease severity was evident also from calculations of the AUDPC for the treatments. The triadimenol treatment contributed to a yield increase in 2 of the 3 yr. In 1981, however, when yields did not increase with the triadimenol seed treatment, the disease levels were lower than in the other 2 yr. There was a significant yield increase in the 1981 plots treated with the low rate of triadimenol when they were sprayed with the foliar fungicide at GS-7. This might indicate that the disease pressure prior to GS-7 had an effect on yield but that interplot interference after GS-7 might have reduced the treatment differences in yield.

In each 3 yr there was a significant amount of powdery mildew on the leaves below those assessed for all treatments except the triadimenol treatments. The lower leaves were not included in this study since Septoria leaf blotch also was present on these leaves and the combination of the two foliar pathogens often resulted in leaf death prior to our final assessment period. While powdery mildew severity values for the leaf below the flag were low, there was a considerable amount of leaf damage on the lower foliage which may have contributed to yield reduction. The inoculum from heavily infected plants in the control plots would have an effect on those in the triadimenol-treated plots; this interference is well documented (8,9). In 1982 and 1983, the larger plot size and the winter barley border rows may have reduced the amount of interference. Martin (13) has stated that large-sized plots are necessary to obtain realistic results in the field.

The AUDPC and yields in 1981 indicated that the high rate of triadimenol was not as effective as the low rate in controlling powdery mildew. There is a possibility that the high rate may have been phytotoxic, thus reducing the effectiveness of the fungicide (4). In preliminary trials with the triadimenol formulation used in 1981, phytotoxicity was evident and the number of tillers per meter of row were reduced (J. A. Frank, *unpublished*). A stand reduction also was observed with the 150 FS formulation in another experiment in 1982 (18). Phytotoxicity was not evident in plots treated with the Baytan 30 formulation.

The PMAA-treated plots and the carboxin-thiram treated plots had lower final disease severities and AUDPC than the controls in 1982 and the AUDPC also was reduced with mercury treatment in 1983. However, there were no yield increases as a result of disease reduction with these two treatments. This disease reduction is difficult to explain since these fungicides have not been reported to be effective against powdery mildew.

Based on this research, it appears that the AUDPC is the best criterion for detecting differences in the effect of seed treatments on foliar disease, especially when there is interplot interference. At a specific assessment period, the difference in disease severity among plots that received the treatments may not be significant but that assessment does not reflect the treatment effect on the epidemic over time. The apparent infection rate ($r$) also does not adequately represent the epidemic, since the $r$ values for 1981 and 1983 are higher for triadimenol-treated plots, which had the lowest disease severity at the final assessment. In 1983, the $r$ value was correlated positively with yield. Similar results were obtained in a study (12) that evaluated fungicidal control of powdery mildew on barley. The primary infections of winter wheat by *E. g.* f. sp. *tritici* in Pennsylvania occur in the fall during the early tillering stages (6). The seedlings that developed from triadimenol-treated seed were not infected by the pathogen. These plants remain disease-free in the spring until they are infected with spores produced on fall-infected plants from plots not treated with triadimenol. Since *E. g.* f. sp. *tritici* is an obligate parasite, it may reproduce at a faster rate on the healthy, triadimenol-treated plants compared to the weakened, untreated plants. The use of $r$ values in these experiments could result in erroneous interpretations while the AUDPC provides the best measure of disease epidemics related to seed treatment and subsequent yield.

Triadimenol appears to have excellent potential as a seed treatment for cereals in the United States. The need for seed treatments has been questioned, especially when yields are not increased (14). However, triadimenol is unique in that it provides control of a foliar pathogen which may cause severe yield losses. It also has been demonstrated to reduce Septoria leaf blotch, another serious foliar disease on wheat (18). In addition to the potential economic return based on yield increase, triadimenol seed treatment may eliminate the need for field applications of foliar fungicides during the growing season.

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