

# Evaluation of Foliar Fungicides for Controlling Fusarium Head Blight of Wheat

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## ABSTRACT

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Fusarium head blight of wheat causes significant reductions in yield, test weight, and seed quality and may be associated with mycotoxin contamination of grain. The objective of this study was to evaluate certain fungicides for effects on head blight severity, deoxynivalenol level, yield, and test weight under conditions of high disease pressure in the field. Fungicides (benomyl, chlorothalonil, fenbuconazole, flusilazole, myclobutanil, potassium bicarbonate, propiconazole, tebuconazole, thiabendazole, and triadimefon plus mancozeb) were applied to wheat cv. Florida 302 at heading stage in 1992 and 1993. Plots were inoculated three times with macroconidia of *Fusarium graminearum* and misted to promote severe head blight epidemics. Head blight incidence was rated at the soft dough stage. Grain yield, test weight, and deoxynivalenol level were determined after harvest. The fungicides tested did not reduce head blight incidence or deoxynivalenol level and did not increase yield or test weight. Prospects for chemical control of head blight are poor.

Fusarium head blight (scab) of wheat (*Triticum aestivum* L.) is caused primarily by *Fusarium graminearum* Schwabe (teleomorph *Gibberella zeae* (Schwein.) Petch) (2,12,13,15). Head blight occurs wherever wheat is grown and is most severe when warm, moist weather occurs during the period from flowering to soft dough stage, when wheat heads are susceptible to infection (12,14). In 1991, rainfall throughout the lower Mississippi

Valley was above normal when wheat was in the heading to soft dough stages, and severe scab developed throughout the region. In 1991, the Arkansas state average wheat yield was only 1,478 kg/ha (22 bu/ac) compared to the previous 5-yr average of 2,876 kg/ha (42.8 bu/ac) (1); and the average grain test weight in the Arkansas Wheat Cultivar Performance Test (56 cultivars) at three locations was only 723 g/L (47.9 lb/bu) (5). There also may have been unseen quality losses from mycotoxins, primarily deoxynivalenol (DON), that have been associated with scabby grain (8,11). Seed quality also was much lower than normal in 1991; and to assure an adequate wheat seed supply, the Arkansas State Plant Board (minutes of meeting on 24 September 1991) allowed seed lots

with 70–84% germination to be sold as substandard certified seed if they met other criteria for certified seed.

In the 1991 head blight epidemic, none of the soft red winter wheat cultivars grown in the region appeared to have adequate head blight resistance, and no crop rotation or cultural practice appeared to reduce head blight incidence (E. A. Milus, *unpublished*). Previous reports indicated that certain foliar fungicides effectively reduced head blight incidence (9), seed infection by *Fusarium* spp. (3,6), or DON levels (3). Our objective was to evaluate fungicides that are currently used on or may be registered for wheat for effects on head blight incidence, DON level, yield, and test weight under conditions of high disease pressure similar those in 1991.

## MATERIALS AND METHODS

Seven single-spored strains of *F. graminearum*, obtained from Luiz Lazo-Anaya, Northrup King Co., Inc., Bay, AR, were used in this study. The strains were isolated in 1991 from scab wheat seeds of six cultivars from five geographically diverse locations in Arkansas and caused head blight on wheat in greenhouse tests (L. Lazo-Anaya, *unpublished*). Strains were stored on air-dried, colonized pieces of filter paper at 4 C, as described by Correll et al (4). Macroconidia were produced on autoclaved air-dried wheat leaves that were placed on water agar. Plates of water

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agar with wheat leaves were inoculated with individual strains using three plugs of potato-dextrose agar (PDA) (8 mm diameter) from a 7-day-old culture. Plates were incubated in the dark at room temperature (approximately 22 C) for 5 days, then incubated for 14 days on a shelf 30 cm below two 40-W fluorescent lamps (one cool white and one near ultraviolet) on a 12-hr photoperiod.

Inoculum was prepared by rubbing leaves and mycelium from 35 plates into 5 L of tap water, filtering through two layers of cheesecloth, bringing the final volume to 8 L, and adding Tween 20 at 0.25 ml/L. Plots were inoculated in the late afternoon at Feekes growth stage [GS, (7)] 10.5.1 (beginning of flowering, 24 April 1992), at GS 10.5.2 (50% flowering, 27 April), and at GS 10.5.3 (flowering complete, 29 April) (7). For each inoculation, inoculum was applied twice at 130 L/ha in opposite directions using a backpack CO<sub>2</sub> sprayer. A sample of the inoculum was frozen to determine conidial concentration by hemacytometer.

Field experiments using the soft red winter wheat cultivar Florida 302 were conducted during the 1992 and 1993 seasons (year of harvest) at the Strawberry Substation, Bald Knob, Arkansas. Plots were planted in early October using a plot drill and were fertilized with nitrogen at 123 kg/ha at GS 4 (beginning of leaf sheath extension). Individual plots were seven rows (1.25 m) by 3.6 m long.

In 1992, the experimental design was a randomized complete block with 12 treatments and four replicates. Fungicides were applied at GS 10.5 (fully headed, 22 April) at a rate of 187 L/ha at 166 kPa using a self-propelled highboy sprayer equipped with flat-fan spray tips. To reduce drift, off-center (half-pattern) tips were used on each end of the spray boom. Treatments were: 1) nonsprayed check, 2) alkylaryl polyethoxylate and sodium salt of alkylsulfonatedalkylate (Latron CS-7 spreader binder check) at 234 ml/ha, 3) noninoculated check with flusilazole (Punch 2E)

at 140 g a.i./ha, 4) flusilazole at 140 g a.i./ha, 5) propiconazole (Tilt 3.6E) at 140 g a.i./ha, 6) triadimefon (Bayleton 50DF) at 70 g a.i./ha plus mancozeb (Dithane 75DF) at 1.68 kg a.i./ha, 7) tebuconazole (Folicur 3.6F) at 140 g a.i./ha, 8) benomyl (Benlate 50DF) at 280 g a.i./ha, 9) thiabendazole (Mertect LSP 2.9F) at 280 g a.i./ha, 10) chlorothalonil (Bravo 720F) at 560 g a.i./ha, 11) myclobutanil (RH-3866 40W) at 140 g a.i./ha, and 12) potassium bicarbonate at 13.4 kg/ha. Latron CS-7 at 234 ml/ha was used with all treatments except propiconazole.

A Nelson Sprayhead II mist system (Hummert International, St. Louis, MO) with grooved plates and no. 16 nozzles (7.6 L/min) was used to provide favorable conditions for infection and systemic spread. The system operated daily from the time of the first inoculation until 8 May, on 11–12 May, and on 14–15 May. On each day, the system operated for 15 min/hr from 0600 hr to 2100 hr, and for 15 min at midnight and 0300 hr, except that the system was shut off at noon on the days of the second and third inoculations.

Head blight incidence on a whole-plot basis was evaluated at GS 11.2 (soft dough, 21 May) by visually estimating the percentage of spikelets blighted. Incidence 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 (>96). Plots were harvested with a plot combine on 13 June. Grain was cleaned twice with an air-blast seed cleaner. Grain moisture and test weight were measured with a GAC II grain analysis computer (Dickey-john Corp., Auburn, IL), and yield was adjusted to 13% moisture.

In 1993, the experiment was conducted in two environments: a high-inoculum level and a low-inoculum level. Each environment was a randomized complete block consisting of 12 treatments and four replicates. The statistical design was a randomized complete block analyzed

across environments. Environment was considered a random effect, and therefore the environment  $\times$  treatment interaction was used to test the significance of the treatment effect.

Procedures were the same as in 1992, except as described here. Treatments were applied at GS 10.3 (50% headed, 29 April). Fenbuconazole (RH-7592 75W) at 140 g a.i./ha, flusilazole at 280 g a.i./ha, and tebuconazole at 280 g a.i./ha replaced chlorothalonil, myclobutanil, and potassium bicarbonate. For each inoculation, 11 plates of inoculum were prepared in 5 L of water. The low inoculum concentration was prepared by bringing 0.5 L of suspension to 8 L, and the high inoculum concentration was prepared by bringing the remaining 4.5 L to 8 L. Conidial concentrations were determined as described previously. Inoculations were done at GS 10.5.2–10.5.3 (4, 5, and 6 May). The mist system was equipped with no. 12 nozzles (4.4 L/min) and was operated for 15 min/hr from 0800 hr until 2000 hr, and at midnight and 0400 hr. The mist system operated daily from the afternoon of 4 May until the morning of 10 May, and on 17, 19, and 21 May. Head blight incidence was evaluated on 14 and 27 May, and the plot was harvested on 28 June.

Deoxynivalenol level of grain samples was determined using a Vomitoxin II quantitative test kit (Neogen Corp., Lansing, MI) that is a direct competitive enzyme-linked immunosorbent assay. Grain samples (50 g each) were prepared according to instructions and diluted 1:10 before testing. Optical density at 630 nm was determined using a Bio-Tek CERES UV900HDi plate reader (Bio-Tek Instruments, Inc., Winooski, VT). Optical densities were converted to ppm DON using Neogen Log/logit 1.0 software. One set of standards (0, 0.5, 1, 2, and 4 ppm DON) was used for each set of 19 samples. Each grain sample was assayed two or three times, and DON levels were averaged before statistical analysis.

**Table 1.** Effects of foliar fungicides on yield, test weight, and head blight incidence, and deoxynivalenol (DON) level of wheat cv. Florida 302 at Bald Knob, Arkansas, in 1993

Treatment <sup>a</sup> , active rate/ha	Yield (kg/ha)	Test wt. (g/L)	Head blight (%)	DON level (ppm)
Nonsprayed check	3,022	761	87	12.0
Latron CS-7 check, 234 ml of product	3,039	765	78	12.2
Benomyl, 280 g	3,231	777	76	12.5
Flusilazole, 140 g	3,106	760	85	19.0
Flusilazole, 280 g	3,170	756	81	18.2
Tebuconazole, 140 g	3,118	766	84	12.9
Tebuconazole, 280 g	3,031	774	87	12.5
Triadimefon, 70 g + mancozeb, 1.68 kg	2,999	761	84	13.9
Propiconazole, 140 g	2,821	764	83	14.8
Thiabendazole, 280 g	2,796	744	84	16.7
Fenbuconazole, 140 g	2,726	754	86	16.8
Noninoculated/flusilazole, 140 g	3,017	766	79	15.4
<i>P</i> value from <i>F</i> test	0.15	0.50	0.12	0.13

<sup>a</sup>Latron CS-7 at 234 ml of product per hectare was used with all treatments except propiconazole.

## RESULTS AND DISCUSSION

In 1992, inoculum concentration for the three inoculations ranged from  $2.9 \times 10^6$  to  $3.0 \times 10^7$  (average  $2.1 \times 10^7$ ) spores per square meter of plot area. More than 99% of the spores were macroconidia, and the rest were ascospores. Head blight incidence was 100% in all inoculated plots regardless of the fungicide treatment, and no grain was found among the chaff at harvest (data not presented). The noninoculated plots that were sprayed with flusilazole averaged 78% head blight incidence and yielded an average of 2,834 kg/ha (42.2 bu/ac) with a test weight of 798 g/L (52.9 lb/bu). The applied inoculum probably caused nearly all of the infections at flowering because of the large difference

in yield and test weight between inoculated and noninoculated plots.

In 1993, the high inoculum concentrations for the three inoculations ranged from  $2.9 \times 10^6$  to  $2.0 \times 10^7$  (average  $1.1 \times 10^7$ ) spores per square meter of plot area. The low inoculum concentrations were approximately 10% of the high concentrations. More than 99% of the spores were macroconidia, and the remainder were ascospores. Head blight incidence was very low on 14 May, and there were no differences among treatments (data not presented). For head blight data recorded on 27 May, inoculum level had a significant effect on disease incidence ( $P = 0.006$ ); however, the low inoculum level averaged 87% incidence compared to 78% for the high level. Inoculum level did not affect yield ( $P = 0.76$ ), test weight ( $P = 0.13$ ), or DON level ( $P = 0.12$ ). Fungicide treatments did not affect head blight incidence, DON level, yield, or test weight (Table 1). DON levels were within the range of previously reported levels in wheat grain (11). Differences in test weight among treatments may have been obscured, and DON levels may have increased because rainy weather delayed harvest about 2 wk. Natural inoculum probably caused most of the infections because disease incidence was higher in the low-inoculum environment, there was no difference between the inoculated and noninoculated checks (Table 1), and disease incidence was approximately 50% in the field surrounding the experiment (E. A. Milus, unpublished).

Both head blight in the field and infection of wheat kernels by *Fusarium* spp. are referred to as scab, but it is important to distinguish between the two symptoms. Head blight is the most important symptom in Arkansas, and reports of mycotoxin contamination of grain and yield, test weight, or seed quality reductions usually have been associ-

ated with severe head blight epidemics (12,13). Snijders and Perkowski (11) found head blight incidence positively correlated with yield reduction, kernel weight reduction, and DON level.

Martin and Johnston (9) reported that propiconazole gave a 41% reduction in head blight, but the treatment was applied twice at 250 g a.i./ha for a total of 500 g a.i./ha, which is four times the allowable rate in the United States. Martin et al (10) later reported that propiconazole at 125 g a.i./ha plus chlorothalonil at 808 g a.i./ha did not control head blight.

Boyacioglu et al (3) reported that several fungicides reduced *Fusarium* infection and/or DON level in wheat grain; however, no head blight symptoms developed in their field experiment. Jacobsen (6) reported that several fungicide treatments reduced scab; however, he too measured grain infection, and no mention was made of head blight symptoms in the field.

In this study, fungicides were applied at heading stage 2–4 days before flowering, and the timing should have been optimum for reducing floret infection by *F. graminearum*. Environmental conditions and inoculum pressure during the infection period were conducive to a severe head blight epidemic; however, conditions were not excessive because yield and test weight averaged 3,006 kg/ha and 762 g/L, respectively, across all treatments. Our results demonstrate that fungicides effective for controlling foliar wheat diseases are not effective for controlling head blight or reducing DON level of the grain in severe epidemics. Some fungicides may be effective under less severe conditions.

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