Difenoconazole Seed Treatment for Control of Dwarf Bunt of Winter Wheat

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ABSTRACT

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We evaluated difenoconazole (Dividend 3FS), thiabendazole (Mertect LSP), triadimenol (Baytan 30F), and carboxin plus thiram (Vitavax 200) as seed treatments for control of dwarf bunt (caused by *Tilletia controversa*) on the susceptible winter wheat (*Triticum aestivum*) cultivars Nugaines and Hatton. Seed was planted at various dates during the fall of 1990 and 1991 at Logan, UT; Kalispell, MT; Pullman, WA; and Cavendish, ID. Dwarf bunt was most severe on plants that had developed to the two- to five-leaf stage in late fall before snowfall. Difenoconazole at 0.12 g a.i./kg provided complete control at all locations when wheat was seeded at intermediate and late dates. A low incidence of dwarf bunt developed when seed treated with difenoconazole was planted at early dates at some locations or when difenoconazole was applied at 0.06 g a.i./kg. The other fungicides tested did not provide adequate control.

Additional keywords: TCK smut

Dwarf bunt, caused by *Tilletia controversa* Kühn in Rabenh., is endemic on winter wheat (*Triticum aestivum* L.) in certain areas of the western and northeastern United States (3). Teliospores of *T. controversa* persist in the soil for many years. The disease, which is also known as dwarf smut, short smut, stunt smut, stubble smut, and TCK smut, was recognized in Montana in 1935 by Young (11) as distinct from common bunt caused by *T. tritici* (Bjerk.) G. Wint. in Rabenh. and *T. laevis* Kühn in Rabenh.

Dwarf bunt is most severe in areas with persistent snow cover, which provides an ideal environment for teliospore germination and infection of wheat seedlings. It reduces wheat yields by replacing the kernels with smut sori. In addition to yield loss, grain quality may be reduced; growers receive lower prices or dockage for grain that is contaminated with sori. Very low levels of teliospore contamination have prevented the export of grain to the People's Republic of China because of a quarantine against the fungus (3,10). The use of resistant cultivars has been the primary means of control in the United States; seeding very early or very late in the autumn also reduces disease incidence (2).

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Of numerous seed treatment chemicals that have been tested, only bitertanol (BAY KWG-0599) and thiabendazole (Mertect LSP) have been reported to provide significant control of dwarf bunt (4,6). However, commercial use of these chemicals has been limited in the United States because they are sometimes phytotoxic and vary in efficacy from year to year. Also, they are less effective when wheat is seeded at intermediate to early dates.

Buchholz and James (1) reported in 1990 that difenoconazole (Dividend, CGA-169374) applied at 0.28 ml per kilogram of wheat seed provided 100% control of dwarf bunt in a plot near Cavendish, ID, seeded on 13 October 1988. We evaluated the effectiveness of difenoconazole as a seed treatment when applied to winter wheat cultivars Nugaines and Hatton seeded on various dates in areas of Idaho, Oregon, Montana, Utah, and Washington that commonly have dwarf bunt.

MATERIALS AND METHODS

Cultivars Hatton and Nugaines, which are susceptible to dwarf bunt, were used for tests in 1990–1991 and 1991–1992. To eliminate possible contamination of seed with common bunt teliospores, seed of each cultivar was surface-disinfested by immersion in a 3:1,000 formalin-water solution for 15 min with occasional stirring (8). The seed was then washed in running tap water for 15 min and air-dried on absorbent paper in a smut-free greenhouse.

Difenoconazole (Dividend 3FS, CIBA Corp., Greensboro, NC) was applied at 0.06 and 0.12 g a.i. per kilogram of seed for tests in 1990–1991 and at 0.06, 0.12, 0.24, and 0.36 g a.i./kg for tests in 1991–1992. Other treatments in each year included thiabendazole (Mertect LSP 30F, Merck & Co., Rahway, NJ) at 1.5 g a.i./kg, carboxin plus thiram (Vitavax 200, Gustafson, Inc., Dallas, TX) at 0.87 g a.i./kg (each component at 0.435 g a.i./kg), and triadimenol (Baytan 30F, Gustafson) at 0.24 g a.i./kg. Each treatment was applied to 1 kg of seed on 5 September 1990 and 26 August 1991 with a Batch Lab seed treater (Gustafson).

Treated and untreated seed of each cultivar was planted in randomized blocks in areas where dwarf bunt commonly occurs near Cavendish, ID; Kalispell, MT; Logan, UT; and Pullman, WA, on several dates in 1990 and 1991 (Table 1). The plots at Logan and Pullman were in places where dwarf bunt nurseries had been grown in previous years. A deep-furrow drill was used to seed four-row plots, 3 m long and 40 cm apart, at Cavendish in 1990. At Logan, seed was planted about 5 cm deep in a single 1.5-m row with a deep-furrow drill. In all other tests, seed was planted by hand in single 1.5-m-long open furrows 40 cm apart and covered with 1–2 cm of soil. The seeding rate was 4 g per 1.5 m. Each treatment was replicated three to six times.

Teliospores collected from smutted wheat heads from each site during the previous season were used to further infest the soil at the corresponding site: teliospores from crushed sori were suspended in tap water, filtered through cheesecloth or a 150-μm screen to remove plant debris, and then sprayed onto the soil surface after seeding at approximately 150 mg per 1.5 m of row on 12 November 1990 and 7 November 1991 at Cavendish, 31 October 1990 and 14 October 1991 at Kalispell, 26 October 1990 and 31 November 1991 at Logan, and 13 November 1990 and 14 November 1991 at Pullman. To determine the developmental stage of the plants before snowfall, we counted the number of leaves on developing wheat plants on 31 October 1990 and 14 October 1991 at Kalispell, 12 November 1990 and 7 November 1991 at Cavendish, 31 November 1991 at Logan, and 5 December 1990 and 3 December 1991 at Pullman. At Pullman, each row was covered with about 8 cm of coarse-graded vermiculite on 5 December 1990 and 3 December 1991 to simulate snow cover. The vermiculite was removed from the plot on 29 February 1991 and 27 February 1992.

Disease (percentage of heads with smut) was assessed during July or early August after the wheat was mature. Each replication consisted of at least 250 heads per plot. The data were analyzed with SAS-GLM and Fisher's protected least significant difference (9).

RESULTS AND DISCUSSION

When seed was not treated with fungicide, dwarf bunt was usually more severe in Hatton than in Nugaines and was most severe on wheat seeded in late September to early October (Table 1). Our results corroborate the earlier report by Hoffmann and Purdy (5) on the effect of the stage of development of winter wheat on infection by *T. controversa.* In our tests, however, even less smut occurred when wheat was planted late enough to limit plant development to one or no leaves before snowfall. At some locations, no smut was detected in the latest plantings.

Hoffmann and Purdy (5) observed maximum infection in plants with one to two tillers during the winter; plants in earlier or later stages of growth developed less infection. Similarly, we found the greatest incidence of dwarf bunt in plants with one to nine leaves, which, according to Klepper et al (7), is equivalent to the one- to three-tiller stage.

Of the seed treatments tested, only difenoconazole provided complete control of dwarf bunt (Tables 2 and 3). Its efficacy was related to date of seeding and to stage of wheat development. Plants with nine or more leaves before snowfall had low percentages of smut when difenoconazole was applied at low rates. Difenoconazole applied at 0.12 g a.i./kg provided complete control of dwarf bunt at all except the earliest planting dates. Difenoconazole applied at 0.36 g a.i./kg eliminated dwarf bunt in all plots except those planted on 9 September 1991 at Pullman. Difenoconazole at 0.12 g a.i./kg gave excellent control of dwarf bunt on wheat planted after the last week of September.

Thiabendazole at 1.5 g a.i. per kilogram of seed has been reported to reduce dwarf bunt (5). In this study, it reduced the incidence of dwarf bunt at most planting dates at the four sites, but it did not provide adequate disease control. Both triadimenol and carboxin plus thiram gave very little control.

Even though treatment with difenoconazole provides exceptional control of dwarf bunt, the most thorough control strategy would be an integrated approach

Table 1. Wheat development before snowfall and incidence of dwarf bunt on non-fungicide-treated Hatton and Nugaines wheat seeded at various dates in 1990 and 1991 at Kalispell, MT; Pullman, WA; Cavendish, ID; and Logan, UT

Location and seeding date	Number of leaves[a]	Infected heads (%)[b]	
		Hatton	Nugaines
Kalispell			
19 September 1990	3	71.7	78.3
3 October 1990	1	26.7	71.7
17 October 1990	0	6.7	2.0
31 October 1990	0	0.7	0.0
LSD ($P = 0.05$)		18.3	4.2
16 September 1991	3	64.0	6.0
30 September 1991	2	4.4	1.0
14 October 1991	0	2.0	0.1
LSD ($P = 0.05$)		4.5	4.3
Pullman			
10 September 1990	17	2.2	0.0
24 September 1990	5	32.8	5.0
8 October 1990	2	17.4	0.1
23 October 1990	1	7.1	0.0
5 November 1990	0	0.0	0.0
LSD ($P = 0.05$)		24.2	6.6
9 September 1991	31	0.4	0.0
23 September 1991	14	2.1	0.6
7 October 1991	3	8.4	2.0
21 October 1991	1	0.5	0.3
6 November 1991	0	0.1	0.6
LSD ($P = 0.05$)		6.0	1.3
Cavendish			
17 September 1990	2	4.3	6.0
4 October 1990	2	13.4	1.7
1 November 1990	0	1.9	0.3
LSD ($P = 0.05$)		9.6	5.9
13 September 1991	9	2.3	0.8
26 September 1991	3	0.2	0.0
9 October 1991	2	1.8	0.3
23 October 1991	0	0.0	0.0
LSD ($P = 0.05$)		1.8	1.2
Logan			
17 September 1991	5	51.0	27.0
9 October 1991	3	86.0	78.0
LSD ($P = 0.05$)		31.5	34.6

[a] Mean number of leaves before snowfall at Kalispell (31 October 1990, 14 October 1991), Pullman (5 December 1990, 3 December 1991), Cavendish (12 November 1990, 7 November 1991), and Logan (31 November 1991). A zero indicates no wheat emergence.

[b] Percentage of heads with visible dwarf bunt symptoms (mean of three to six replications). Means within a location-year and column were compared with Fisher's protected least significant difference (LSD) ($P = 0.05$).

Table 2. Comparison of seed treatments for control of dwarf bunt in wheat cultivars Hatton and Nugaines seeded on various dates in 1990 at Logan, UT; Kalispell, MT; Pullman, WA; and Cavendish, ID

	Infected heads (%)[a]											
	Logan	Kalispell				Pullman				Cavendish		
Treatment and rate (g a.i./kg)	3 Oct.	19 Sept.	3 Oct.	17 Oct.	31 Oct.	10 Sept.	24 Sept.	23 Oct.	5 Nov.	17 Sept.	4 Oct.	1 Nov.
Hatton												
Control	91	72	27	7.0	0.7	2.2	33	7.1	0.0	4.3	13.4	1.9
Carboxin + thiram, 0.87[b]	90	35	35	1.0	0.0	3.5	21	2.4	0.0	0.8	5.3	0.0
Triadimenol, 0.24	83	33	53	0.0	0.0	5.6	8	2.0	0.0	0.0	6.6	0.1
Thiabendazole, 1.5	35	20	10	0.0	0.0	2.8	19	0.4	0.0	0.2	2.0	0.0
Difenoconazole, 0.12	0	0	0	0.0	0.0	1.0	1	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.24	0	0.7	0	0.0	0.0	0.4	0	0.0	0.0	0.0	0.0	0.0
LSD ($P = 0.05$)	12	32	29	2.0	1.3	6.1	24	6.6		1.6	8.2	1.9
Nugaines												
Control	76	78	72	2.0	0.0	0.0	5.0	0.0	0.0	6.0	1.7	0.3
Carboxin + thiram, 0.87[b]	48	67	68	2.1	0.0	0.1	5.0	0.0	0.0	4.5	0.8	0.0
Triadimenol, 0.24	43	78	72	3.0	0.0	0.6	1.0	0.0	0.0	0.0	0.9	0.0
Thiabendazole, 1.5	37	23	0.4	0.0	0.0	0.4	0.0	0.0	0.0	1.3	6.4	0.0
Difenoconazole, 0.12	0	0.8	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.24	0.1	0.4	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD ($P = 0.05$)	25	33	17	3.1		0.5	8.5			3.6	6.5	0.3

[a]Mean percentage of heads with dwarf bunt assessed on a minimum of 250 heads per plot in each of three replications at Kalispell, four at Cavendish, five at Pullman, and six at Logan. Means within a cultivar and column were compared with Fisher's protected least significant difference (LSD) ($P = 0.05$).
[b]Carboxin at 0.435 g a.i./kg, thiram at 0.435 g a.i./kg.

Table 3. Comparison of seed treatments for control of dwarf bunt in wheat cultivars Hatton and Nugaines seeded on various dates in 1991 at Logan, UT; Kalispell, MT; Pullman, WA; and Cavendish, ID

	Infected heads (%)[a]													
	Logan		Kalispell			Pullman					Cavendish			
Treatment and rate (g a.i./kg)	17 Sept.	9 Oct.	16 Sept.	30 Sept.	14 Oct.	9 Sept.	23 Sept.	7 Oct.	21 Oct.	6 Nov.	13 Sept.	26 Sept.	9 Oct.	23 Oct.
Hatton														
Control	51	86	64	4.0	2.0	0.4	2.1	8.4	0.5	0.1	3.0	0.3	0.8	0.0
Carboxin + thiram, 0.87[b]	51	86	28	1.9	1.4	0.4	1.0	6.3	1.2	0.3	0.8	0.5	3.0	0.0
Triadimenol, 0.24	24	29	24	3.4	1.0	0.2	3.3	6.4	1.3	0.1	0.3	0.5	0.0	0.0
Thiabendazole, 1.5	36	88	25	0.8	0.0	0.2	2.5	6.2	0.0	0.0	3.8	0.5	0.3	0.0
Difenoconazole, 0.06	0.6	0	0.4	0.0	0.0	0.4	1.4	0.1	0.0	0.0	0.2	0.0	0.0	0.0
Difenoconazole, 0.12	0	0	0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.24	0	0	0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.36	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD ($P = 0.05$)	21.7	9	20	2.6	1.9	0.4	1.8	7.3	1.1	0.2	4.1	0.8	1.4	
Nugaines														
Control	27	78	6	1.0	0.1	0.0	0.6	2.0	0.3	0.6	1.3	0.0	0.0	0.0
Carboxin + thiram, 0.87[b]	33	78	6	0.5	1.0	0.0	1.1	1.5	0.2	0.0	0.0	0.5	0.5	0.8
Triadimenol, 0.24	2	76	4	0.3	0.2	0.0	0.0	1.3	0.1	0.5	0.0	0.0	0.4	0.0
Thiabendazole, 1.5	28	85	7	0.1	1.0	0.0	0.3	2.3	0.5	0.8	0.0	1.3	0.5	0.0
Difenoconazole, 0.06	4	0.4	0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.12	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.24	0	0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Difenoconazole, 0.36	0	0	0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
LSD ($P = 0.05$)	21	15.5	4	0.8	1.5	0.1	0.7	1.8	0.3	0.9	1.3	0.9	0.8	0.8

[a]Mean percentage of heads with dwarf bunt assessed on a minimum of 250 heads per plot in each of four replications at Cavendish, five at Logan and Kalispell, and six at Pullman. Means within a cultivar and column were compared with Fisher's protected least significant difference (LSD) ($P = 0.05$).
[b]Carboxin at 0.435 g a.i./kg, thiram at 0.435 g a.i./kg.

combining difenoconazole treatment of resistant cultivars with late planting. Using resistant cultivars and modifying the seeding date to influence the stage of wheat development before winter snowfall greatly reduces but does not eliminate dwarf bunt. Early planting reduces dwarf bunt but also reduces the effectiveness of difenoconazole. Late planting increases the effectiveness of difenoconazole and reduces dwarf bunt incidence. However, late planting may increase the risk of winterkill, weeds, soil erosion, and reduced yields (2). In addition to reducing losses caused by dwarf bunt and providing smut-free grain for the export market, the use of difenoconazole would lower the possibility of the development of new, virulent, and highly destructive races of *T. controversa*.

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