Effect of Winter Wheat Cultivar and Difenoconazole Seed Treatment on Dwarf Bunt

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ABSTRACT

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Four hard red and four soft white winter wheat cultivars (*Triticum aestivum*) of varying susceptibility to dwarf bunt (*Tilletia controversa*) were evaluated with and without difenoconazole seed treatment at 0.24 g a.i./kg. Difenoconazole provided complete control of dwarf bunt regardless of cultivar susceptibility. Percent winter kill was less among cultivars treated with difenoconazole in 1993. Winter wheat yields of difenoconazole treated and nontreated cultivars were similar in 1992, but average yields of treated cultivars were 21% greater in 1993, improving adjusted gross returns by $147/ha.

Additional keyword: TCK

Dwarf bunt of winter wheat, causal organism *Tilletia controversa* Kühn, was first identified in Montana by P. A. Young in 1935 and has been recognized since as a serious disease problem in localized areas with early and persistent snow cover (4,9,12). Dwarf bunt is a serious production problem in the Flathead Valley area near Kalispell, MT, which has an ideal environment for teliospore germination and infection.

Yield loss due to dwarf bunt is a major concern. Yield losses are reported to be proportional to the level of infection and occur as a result of the wheat kernel being replaced with bunt spores (1,4,9). A second concern is the loss of winter wheat grain markets. Since 1973, the People's Republic of China has imposed a zero tolerance quarantine against the importation of grain containing teliospores of dwarf bunt (2,7,11).

The control of dwarf bunt has been restricted essentially to the use of resistant cultivars. Resistant cultivars used in the Flathead Valley area are limited to Winridge, a hard red winter wheat, and Lewjain, a soft white winter wheat. Both cultivars derive their resistance from PI 178383. Virulence against the resistance of PI 178383 has been detected in dwarf bunt populations (4,9), leaving the currently recommended cultivars vulnerable to races of *T. controversa*. Alternative control measures are needed until additional resistance can be incorporated into locally adapted cultivars.

Chemical controls have not been a viable option. Dwarf bunt control has been achieved with some chlorinated hydrocarbons, but these materials have not been utilized due to environmental concerns (4,6,9). Systemic fungicides applied as a seed dressing also have been evaluated, but results have been inconsistent and cost prohibitive (3,5,6).

Difenoconazole is a new fungicide seed treatment reported to control fungi in a number of taxonomic groups. Difenoconazole was developed by Ciba Geigy Corporation under the code CGA-169374. Difenoconazole is in the triazole class of fungicides, and its mode of action involves inhibition of demethylation of sterols. Sitton et al. (10) observed excellent control of dwarf bunt when winter wheat was treated with difenoconazole at 0.24 g a.i./kg of seed.

Difenoconazole has been evaluated on a limited number of winter wheat cultivars. Dwarf bunt control on cultivars ranging in susceptibility and resistance has not been examined. In addition, economic justification for the use of difenoconazole in terms of yield response is lacking. We undertook this research to evaluate the efficacy of difenoconazole for dwarf bunt control and to determine the associated yield response between winter wheat classes and among cultivars with varying degrees of dwarf bunt resistance.

MATERIALS AND METHODS

Experiments were conducted at the Northwestern Agricultural Research Center near Kalispell, MT, during the 1991 to 1992 and 1992 to 1993 growing seasons. The soil was a Creston silt loam (coarse silty, mixed, Pachic Haploxeroll) with 4.7% organic matter, pH 7.5. Experiments were arranged as randomized complete block designs with four replications. Treatments consisted of four hard red and four soft white winter wheat cultivars treated or not treated with difenoconazole. Hard red cultivars evaluated were Judith, Tiber, Rocky, and Winridge. The soft white cultivars were Luke, Nugaines, Stephens, and Lewjain. These cultivars vary in susceptibility to dwarf bunt, with Winridge and Lewjain being highly resistant to the disease.

Four weeks prior to planting, seeds were surface-disinfected with a 37% formaldehyde solution for 15 min with occasional stirring and then rinsed with tap water for 15 min and air-dried on adsorbent paper. Seeds were treated with difenoconazole at 0.24 g a.i./kg by applying aliquots of a 1.5% water/difenoconazole solution to 209 g of seed in a metal, tumbling seed treater.

Cultivars were seeded with a cone-fed, double-disk, press-type research plot seeder at 67 kg/ha to a depth of 3.0 cm. Seeding dates were 3 October 1991 and 22 September 1992. Individual plots were 1.2 × 3.0 m, consisting of four 30-cm rows.

To insure adequate disease pressure, the local dwarf bunt population was supplemented by spraying cultivars at the 3 leaf stage with an inoculum solution of dwarf bunt teliospores at 1×10^6 spores per ml. Inoculum was prepared using the procedures described by Sitton et al. (10) and involved suspending 27 kg of infected wheat heads in 38 liters of water for 15 min with occasional stirring. The infected heads were obtained from susceptible cultivars previously grown in the western regional soft white and hard red winter wheat trials at Kalispell, MT. The suspension was filtered twice through cheesecloth and applied to the test area with a tractor-mounted plot sprayer calibrated to deliver 215 liters/ha. The experimental area was sprayed until the entire 38-liter solution had been applied. Inoculum was applied on 15 and 1 October 1991 and 1992, respectively.

Dwarf bunt incidence was determined by counting the total number of wheat heads and the number of infected heads for 0.25 m of row during early July each year. Plots were harvested during early August, and yields were expressed at 13% moisture. Grain subsamples were taken to determine test weight. A prolonged period of continuous snow cover during 1992 to 1993 resulted in substantial winter kill and allowed for a visual estimate of stand loss. Winter kill evaluations were made on 1 July 1993.

An economic analysis was conducted by multiplying the wheat selling price by the grain yield for each treatment. The 5 year average for soft white ($14.06/100 kg) and hard red ($14.31/100 kg) number 1 grade

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winter wheat was used as the price for each wheat class. This was a conservative estimate in that it did not consider dockage for dwarf bunt contamination or variations in test weight. A cost of $7.41/ha was subtracted from the difenoconazole treatments to obtain an adjusted gross return value. This value was based on the seeding rate used in the experiment and the suggested retail price of $11.00/100 kg of seed for the difenoconazole treatment. The cultivars used in the experiment were public cultivars that have equal costs.

All data were subjected to analysis of variance. Due to treatment by year interactions, each year was analyzed separately. Contrast comparisons were used to partition main effect and interaction sums of squares into single degree-of-freedom components.

RESULTS AND DISCUSSION

1992. Difenoconazole provided complete control of dwarf bunt for all cultivars evaluated. Differences in disease incidence were noted between winter wheat classes and among cultivars not treated with difenoconazole. Soft white cultivars were less susceptible to dwarf bunt compared to hard red cultivars (Table 1, contrasts 2 and 4). There were no differences in disease incidence between treated and nontreated soft white cultivars (contrasts 5 through 9). Low disease pressure may have contributed to the lack of treatment differences and could be due to the late planting date and the fact that there were only 23 days of continuous snow cover during 1992.

Higher levels of dwarf bunt infection were observed in the hard red cultivars, and seed treatment effects were apparent (contrasts 10 through 13). Nontreated cultivar Judith demonstrated the greatest degree of susceptibility, followed by Rocky and Tiber. Because Winridge was resistant, it did not benefit from the difenoconazole treatment.

Although difenoconazole provided complete control of dwarf bunt, treatment differences were not detected with respect to winter wheat yield (contrasts 1 and 5 through 14). Soft white cultivars yielded more than the hard red cultivars; however, the latter had greater test weights (contrasts 2 through 4). The main effect of seed treatment on soft white cultivar test weight was nonsignificant (contrast 5). However, test weight for Stephens was slightly reduced when treated with difenoconazole ($PR > F = 0.07$). Test weights for the hard red cultivars were not affected by seed treatment (contrasts 10 through 14).

1993. Disease incidence was higher in 1993 than in 1992, possibly due to the earlier planting date and a longer period of continuous snow cover. There were 105 days of continuous snow cover from 4 December through 18 March. Difenoconazole again provided complete control of dwarf bunt in spite of the higher disease incidence (Table 2, contrast 3).

As in the previous year, the soft white winter wheat cultivars were less susceptible to dwarf bunt compared to the hard red winter wheat cultivars (contrasts 2 and 4). Infection levels for the nontreated soft white winter wheat cultivars averaged 4.8% compared to 15% for the hard red winter wheat cultivars (contrast 4). Unlike 1992, seed treatment effects were significant for the soft white cultivars (contrast 5). Difenoconazole reduced dwarf bunt infection levels the most for cultivars Nugaines and Luke ($PR > F = 0.02$ and 0.10, respectively). Nontreated Stephens showed a slight incidence of infection, and Lewjain was resistant. Seed treatment effects were significant for all hard red cultivars except

Table 1. Contrast comparisons of percent dwarf bunt-infected winter wheat heads,[a] yield, and test weight among soft white and hard red winter wheat classes and cultivars when treated (T) or not treated (NT) with difenoconazole during 1992

	Contrast	Infected heads		Yield		Test weight	
		%	*PR* > *F*	kg/ha	*PR* > *F*	kg/m³	*PR* > *F*
1	Winter wheat T vs NT	0.0 vs 6.0	0.00	7,457 vs 7,534	0.67	752 vs 757	0.14
2	Hard red vs soft white	5.6 vs 0.3	0.00	7,157 vs 7,833	0.00	764 vs 744	0.00
3	Hard red T vs soft white T	0.0 vs 0.0	1.00	7,062 vs 7,851	0.00	761 vs 742	0.00
4	Hard red NT vs soft white NT	11.3 vs 0.6	0.00	7,252 vs 7,816	0.03	767 vs 747	0.00
5	Soft white T vs NT	0.0 vs 0.6	0.64	7,851 vs 7,816	0.89	742 vs 747	0.32
6	Luke T vs NT	0.0 vs 1.0	0.72	8,154 vs 7,383	0.14	757 vs 755	0.83
7	Nugaines T vs NT	0.0 vs 0.7	0.80	7,538 vs 7,766	0.66	738 vs 745	0.44
8	Stephens T vs NT	0.0 vs 0.9	0.75	7,669 vs 7,995	0.53	738 vs 756	0.07
9	Lewjain T vs NT	0.0 vs 0.0	1.00	8,045 vs 8,122	0.88	736 vs 732	0.68
10	Hard red T vs NT	0.0 vs 11.3	0.00	7,062 vs 7,252	0.46	761 vs 767	0.28
11	Judith T vs NT	0.0 vs 20.0	0.00	8,286 vs 7,979	0.55	761 vs 755	0.52
12	Tiber T vs NT	0.0 vs 6.8	0.02	6,882 vs 7,501	0.23	781 vs 788	0.52
13	Rocky T vs NT	0.0 vs 18.4	0.00	6,472 vs 6,165	0.55	743 vs 750	0.46
14	Winridge T vs NT	0.0 vs 0.0	1.00	6,609 vs 7,363	0.15	761 vs 775	0.15

[a] Percent infected heads determined by counting total winter wheat heads and number of infected heads for 0.25 m of row.

Table 2. Contrast comparisons for percent dwarf bunt-infected winter wheat heads,[a] winter kill, yield, and test weight among soft white and hard red winter wheat classes and cultivars when treated (T) or not treated (NT) with difenoconazole during 1993

	Contrast	Infected heads		Winter kill		Yield		Test weight	
		%	*PR* > *F*	%	*PR* > *F*	kg/ha	*PR* > *F*	kg/m³	*PR* > *F*
1	Winter wheat T vs NT	0.0 vs 9.9	0.00	34 vs 48	0.00	6,304 vs 5,208	0.00	675 vs 660	0.00
2	Hard red vs soft white	7.5 vs 2.4	0.00	44 vs 39	0.17	6,503 vs 5,008	0.00	714 vs 618	0.00
3	Hard red T vs soft white T	0.0 vs 0.0	1.00	36 vs 33	0.53	7,189 vs 5,419	0.00	726 vs 622	0.00
4	Hard red NT vs soft white NT	15.0 vs 4.8	0.00	52 vs 45	0.19	5,818 vs 4,598	0.00	703 vs 615	0.00
5	Soft white T vs NT	0.0 vs 4.8	0.04	33 vs 45	0.02	5,419 vs 4,598	0.00	622 vs 615	0.35
6	Luke T vs NT	0.0 vs 7.7	0.10	28 vs 42	0.18	5,783 vs 5,057	0.19	634 vs 635	0.95
7	Nugaines T vs NT	0.0 vs 11.2	0.02	78 vs 85	0.53	4,013 vs 2,702	0.02	603 vs 573	0.04
8	Stephens T vs NT	0.0 vs 0.3	0.94	13 vs 30	0.10	6,467 vs 5,580	0.11	642 vs 651	0.55
9	Lewjain T vs NT	0.0 vs 0.0	1.00	13 vs 25	0.26	5,415 vs 5,056	0.52	610 vs 603	0.62
10	Hard red T vs NT	0.0 vs 15.0	0.00	36 vs 52	0.00	7,189 vs 5,818	0.00	726 vs 703	0.00
11	Judith T vs NT	0.0 vs 25.2	0.00	33 vs 46	0.22	7,503 vs 5,274	0.00	712 vs 679	0.03
12	Tiber T vs NT	0.0 vs 17.2	0.00	24 vs 55	0.00	6,813 vs 5,370	0.01	747 vs 723	0.11
13	Rocky T vs NT	0.0 vs 17.6	0.00	58 vs 80	0.04	7,797 vs 5,958	0.00	749 vs 727	0.13
14	Winridge T vs NT	0.0 vs 0.0	1.00	30 vs 28	0.84	6,643 vs 6,670	0.96	699 vs 685	0.35

[a] Percent infected heads determined by counting total winter wheat heads and number of infected heads for 0.25 m of row.

Winridge (contrasts 10 through 14). Among the hard red cultivars, Judith again exhibited the highest level of infection, followed by Rocky and Tiber.

Stand loss differences associated with winter kill were observed among treatments in 1993; however, the severity of stand loss was less for difenoconazole treated cultivars (contrast 1). Typically, winter kill is a function of snow mold infection (*Typhula* spp.) and winter hardiness. Although causal organisms were not isolated and identified, we feel it is of value to note this observation.

Dwarf bunt is known to predispose infected plants to winter kill as well as other diseases (1). Difenoconazole may have indirectly or directly decreased winter kill stand loss by reducing the incidence of dwarf bunt or by controlling or suppressing snow mold organisms. Regardless of the means, winter kill was reduced, and the main effect of seed treatment was significant for both winter wheat types (contrasts 5 and 10).

Although not statistically significant, winter kill was less severe with the soft white winter wheat class than with the hard red winter wheat class (contrasts 2 and 4). This corresponds with the severity of dwarf bunt infection between the winter wheat classes, which may suggest that the reduction in winter kill was partially related to the severity of dwarf bunt infection. Among the soft white cultivars, percent winter kill was most severe for Nugaines, Luke, Stephens, and Lewjain, respectively. Although the main effect of difenoconazole on winter kill of soft white winter wheat cultivars was significant, Stephens was the only soft white cultivar to substantially respond to the seed treatment based on probability levels (contrasts 6 through 9). Among the hard red cultivars, winter kill was most severe for Rocky, Tiber, Judith, and Winridge, respectively. Difenoconazole significantly reduced winter kill for cultivars Tiber and Rocky (contrasts 12 and 13).

Yield differences with difenoconazole were apparent in 1993. Overall yields were 21% greater when difenoconazole was used as a seed treatment (contrast 1). Yield differences in 1993 could be attributed to higher dwarf bunt infection levels compared to 1992, as well as to stand losses associated with the winter kill complex. Although there is no information on the efficacy of this compound for the control of snow mold organisms, the compound is labeled for the control or suppression of several pathogens. Since difenoconazole reduced stand losses, it is not unreasonable to suspect that the yield differences may be due to the control of organisms other than dwarf bunt.

In contrast to 1992, the soft white winter wheat class had lower yields than the hard red winter wheat class (contrasts 2 through 4). This occurred even though the soft white wheats had lower levels of dwarf bunt infection and a slightly lower incidence of winter kill. Nonetheless, soft white cultivars did benefit from difenoconazole treatment. Averaged over soft white cultivars, yields were 5,419 kg/ha when difenoconazole was used compared to 4,598 kg/ha in the absence of the seed treatment (contrast 5). The main effect of seed treatment on soft white winter wheat yield was significant; however, individual cultivars varied in yield response as a function of the seed treatment. Yield of Nugaines improved most, followed by Stephens and Luke, respectively (contrasts 7, 8, and 6, respectively). Hard red cultivar yields were improved by 23% when difenoconazole was used as a seed treatment (contrast 10). Difenoconazole improved yields for all of the dwarf bunt-susceptible hard red winter wheat cultivars, but yield of resistant cultivar Winridge was not affected (contrasts 11 through 14).

Averaged over cultivars, difenoconazole resulted in higher test weights (contrast 1). As was the case in 1992, hard red wheats had greater test weights than soft white wheats (contrasts 2 through 4). Except for Nugaines, soft white winter wheat test weights were not affected by seed treatment (contrasts 5 through 9). Averaged over hard red wheat cultivars, difenoconazole resulted in greater test weights, with Judith demonstrating the most significant increase (contrasts 10 and 11).

Economic return. The higher wheat yields obtained from difenoconazole treated seed in 1993 improved adjusted gross returns by $147/ha (Table 3, contrast 1). Averaged over soft white winter wheat cultivars, adjusted gross return was $754/ha when difenoconazole was used compared to $646/ha in the absence of the seed treatment (contrast 5). Although the main effect of seed treatment on soft white cultivar adjusted gross return was significant, Nugaines was the only cultivar to benefit from a statistical perspective (contrast 7). Hard red cultivar adjusted gross returns were improved by $187/ha when difenoconazole was used as a seed treatment (contrast 10). Difenoconazole improved adjusted gross returns for all of the dwarf bunt-susceptible hard red cultivars, but the adjusted gross return for resistant cultivar Winridge was not affected (contrasts 11 through 14).

The lack of significant yield differences in 1992 between treated and nontreated cultivars suggests that the $7.41/ha investment for the difenoconazole seed treatment was not worthwhile (Table 3). However, the economic return of difenoconazole for dwarf bunt control also must consider the dockage incurred when selling contaminated grain. Locally, dwarf bunt-infested grain is discounted at $0.51/100 kg for contamination levels greater than 1%. For a yield of 5,000 kg/ha, the resultant dockage would be in excess of $25/ha. The elimination of grain discounts alone justifies the cost of $7.41/ha for the use of difenoconazole. Economically, the use of difenoconazole also can be supported in part because it controls other pathogens as well as dwarf bunt, including common bunt and various root-invading fungal pathogens. As a result, it does not need to be combined with other existing fungicides.

Difenoconazole provided complete control of dwarf bunt during both years of this study and did not cause any noticeable phytotoxicity. The use of this material in conjunction with an integrated control program, including resistant cultivars and late plantings, could dramatically reduce the incidence of dwarf bunt and allow producers to grow a wider range of more profitable winter wheat cultivars.

The use of difenoconazole may not have an immediate impact on trade with China or the lifting of the quarantine due to dwarf bunt contamination of combines, elevators, grain-handling equipment, and rail cars (8). Yet, with an effective control available, the People's Republic of China may eventually allow wheat imports into their country.

Table 3. Contrast comparisons for adjusted gross return[a] among soft white and hard red winter wheat classes and cultivars when treated (T) or not treated (NT) with difenoconazole during 1992 and 1993

		1992		1993	
	Contrast	Return ($/ha)	*PR > F*	Return ($/ha)	*PR > F*
1	Winter wheat T vs NT	1,049 vs 1,067	0.47	886 vs 739	0.00
2	Hard red vs soft white	1,020 vs 1,097	0.00	925 vs 700	0.00
3	Hard red T vs soft white T	1,003 vs 1,096	0.01	1,019 vs 754	0.00
4	Hard red NT vs soft white NT	1,037 vs 1,098	0.10	832 vs 646	0.00
5	Soft white T vs NT	1,096 vs 1,098	0.94	754 vs 646	0.00
6	Luke T vs NT	1,139 vs 1,038	0.17	805 vs 711	0.23
7	Nugaines T vs NT	1,052 vs 1,092	0.59	556 vs 380	0.03
8	Stephens T vs NT	1,070 vs 1,124	0.47	901 vs 784	0.14
9	Lewjain T vs NT	1,123 vs 1,141	0.80	754 vs 710	0.58
10	Hard red T vs NT	1,003 vs 1,037	0.35	1,019 vs 832	0.00
11	Judith T vs NT	1,178 vs 1,142	0.62	1,066 vs 755	0.00
12	Tiber T vs NT	977 vs 1,073	0.19	968 vs 768	0.01
13	Rocky T vs NT	919 vs 882	0.62	1,108 vs 853	0.00
14	Winridge T vs NT	938 vs 1,054	0.12	934 vs 955	0.88

[a] Adjusted gross return determined by multiplying wheat selling price by grain yield for each treatment and subtracting the cost of difenoconazole from the treatments that received the fungicide.

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