Systemic Fungicides for Control of Dwarf Bunt of Wheat: I. Seed Treatment

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ABSTRACT

Hoffmann, J. A., Dewey, W. G., Call, J. E., and Rine, S. M. 1983. Systemic fungicides for control of dwarf bunt of wheat: I. Seed treatment. Plant Disease 67:294-297.

Twenty-two formulations with known or suspected systemic fungicidal activity were tested as seed treatments for the control of dwarf bunt of wheat (*Triticum aestivum*) caused by *Tilletia controversa* during the 5-yr period 1976–1980. Many of the formulations reduced dwarf bunt incidence, particularly at higher rates of application, but few provided practical control (less than 10% incidence). Several of the formulations reduced stands and seedling vigor. Of the materials tested, thiabendazole (Mertect LSP) exhibited the best control with the least adverse effects. The use of solvent carriers failed to increase the efficacy of the seed treatments.

Dwarf bunt of wheat (*Triticum aestivum* L.), caused by *Tilletia controversa* Kühn, is the most serious disease of winter wheat in Utah. It is also a major disease problem in other winter wheat areas of the Intermountain Region and the Pacific Northwest. Cultivar resistance to the pathogen has been the principal means of control; however, the ability of the causal organism to develop new pathogenic races has necessitated a continual replacement of dwarf bunt-resistant cultivars. An effective, economically feasible chemical control would supplement cultivar resistance and prolong the effectiveness of a diminishing supply of host genes resistant to bunt.

Because infection of wheat by *T. controversa* results from soilborne inoculum and occurs long after seedling emergence (6,11,12), the standard seed treatments effective against the common bunt pathogens (*T. caries* (DC.) Tul. and *T. foetida* (Wallr.) Liro) do not control dwarf bunt (9,10). The increased development of systemic fungicides, particularly the success of systemics in controlling loose smuts (*Ustilago* spp.) in cereals (8), has revived interest in the potential for chemical control of *T. controversa*. Widely varying results have been reported on the use of systemic fungicides for controlling dwarf bunt.

Contribution of Agricultural Research Service, U.S. Department of Agriculture, in cooperation with the Agricultural Experiment Stations of Idaho, Montana, and Utah. Journal Series Paper 2710 of the Utah Agricultural Experiment Station.

Partially funded by a grant from the Pacific Northwest Regional Commission, administered through the Oregon State Department of Agriculture.

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Accepted for publication 1 August 1982.

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Table 1. Effectiveness of fungicides as seed treatments for control of dwarf bunt (*Tilletia controversa*)

Fungicide and formulation[a]	Rate (g or ml a.i./kg)	Mean percent dwarf bunt	No. of locations × yr tested
Untreated check	0.0	54	15
Benomyl 50W	0.6	36	7
Benomyl 50W	1.0	57	8
Benomyl 50W	1.2	29	7
Benomyl 50W	2.1	47	8
Benomyl 50W	2.5	24	7
Benomyl 50W	4.2	36	8
Benodanil 50W	1.0	66	4
Benodanil 50W	2.1	65	4
Benodanil 50W	4.2	56	4
Carbendazim + maneb 15 + 60W	1.0	52	4
Carbendazim + maneb 15 + 60W	2.1	57	4
Carbendazim + maneb 15 + 60W	4.2	57	4
Carboxin 75W	1.0	60	8
Carboxin 75W	1.2	38	3
Carboxin 75W	2.1	65	8
Carboxin 75W	2.5	40	3
Carboxin 75W	4.2	64	8
CGA-39896 25W	1.0	60	8
CGA-39896 25W	2.1	56	8
CGA-39896 25W	4.2	75(PS)[b]	8

(*continued on next page*)

Table 1. (*continued from preceding page*)

Fungicide and formulation[a]	Rate (g or ml a.i./kg)	Mean percent dwarf bunt	No. of locations × yr tested
Etaconazole 21.5W	0.3	7	4
Etaconazole 21.5W	0.6	5(PS)	7
Etaconazole 21.5W	1.0	17	4
Etaconazole 21.5W	1.2	1(PS)	7
Etaconazole 21.5W	2.1	2(PS)	4
Etaconazole 21.5W	2.5	0(PS)	3
Etaconazole 21.5W	4.2	0(PS)	4
Fenapanil 36EC	1.1	63	4
Fenapanil 36EC	2.2	48	4
Fenapanil 36EC	4.4	33(PS)	4
Fenapanil 24.2L	1.1	61	4
Fenapanil 24.2L	2.2	47	4
Fenapanil 24.2L	4.4	33(PS)	4
Fenarimol 12.5L	1.1	32(PS)	8
Fenarimol 12.5L	2.2	50(PS)	8
Fenarimol 12.5L	4.4	22(PS)	8
Methfuroxam 75W	0.6	40	7
Methfuroxam 75W	1.0	57	12
Methfuroxam 75W	1.2	39	7
Methfuroxam 75W	2.0	51	12
Methfuroxam 75W	2.5	24	7
Methfuroxam 75W	4.2	40	12
Methfuroxam 6.2F	0.3	33	7
Methfuroxam 6.2F	0.6	29	7
Methfuroxam 6.2F	1.1	51	8
Methfuroxam 6.2F	1.3	22	7
Methfuroxam 6.2F	2.2	44	8
Methfuroxam 6.2F	4.4	33	8
Methfuroxam + thiram 5 + 25.8F	1.1	30	4
Methfuroxam + thiram 5 + 25.8F	2.2	23	4
Methfuroxam + thiram 5 + 25.8F	4.4	22	4
Methfuroxam + zinc ion-maneb complex 12.5 + 62.5W	1.0	71	4
Methfuroxam + zinc ion-maneb complex 12.5 + 62.5W	2.1	66	4
Methfuroxam + zinc ion-maneb complex 12.5 + 62.5W	4.2	60	4
Nuarimol 70W	0.6	55	3
Nuarimol 70W	1.2	43	3
Nuarimol 70W	2.5	40	3
Nuarimol 9.5L	1.1	45	3
Nuarimol 9.5L	2.2	NS[b]	3
Nuarimol 9.5L	4.4	NS	3
Thiabendazole 60W	0.6	22	7
Thiabendazole 60W	1.0	30	8
Thiabendazole 60W	1.2	9	7
Thiabendazole 60W	2.1	22	8
Thiabendazole 60W	2.5	5	7
Thiabendazole 60W	4.2	8	8
Thiabendazole 42F	1.1	27	4
Thiabendazole 42F	2.2	11	4
Thiabendazole 42F	4.4	4	4
Thiabendazole 30F	0.6	19	7
Thiabendazole 30F	1.1	35	4
Thiabendazole 30F	1.3	4	7
Thiabendazole 30F	2.2	16	4
Thiabendazole 30F	2.6	1	7
Thiabendazole 30F	4.4	10	4
Triadimefon 25W	0.6	33	7
Triadimefon 25W	1.0	66	8
Triadimefon 25W	1.2	23	7
Triadimefon 25W	2.1	45	8
Triadimefon 25W	2.5	11	7
Triadimefon 25W	4.2	30(PS)	8
Triadimenol 25W	0.6	49	3
Triadimenol 25W	1.2	18	3
Triadimenol 25W	2.5	8	3
Triadimenol 14F	0.6	17	4
Triadimenol 14F	1.3	5	4
Triadimenol 14F	2.6	1	4
Triazbutil 70L	1.1	63	4
Triazbutil 70L	2.2	71	4
Triazbutil 70L	4.4	63	4

[a]Percentage of active ingredient (a.i.) and formulation type (W = wettable powder, EC = emulsifiable concentrate, L = liquid, and F = flowable).
[b]PS = poor stand and NS = no stand.

Seed treatments with carboxin and oxycarboxin, which are effective against loose smuts, have not controlled dwarf bunt (3,4), but various thiabendazole formulations have shown fair-to-good control when applied as seed treatments (2,3,5). Control with thiabendazole, however, has been somewhat erratic from year to year and from location to location.

New materials with suspected systemic activity against bunt fungi have become available in recent years. The purpose of this study was to examine the potential of these new compounds, together with such older systemics as benomyl, carboxin, and thiabendazole, in an effort to find a more consistently effective and economical seed treatment for controlling dwarf bunt.

MATERIALS AND METHODS

Twenty-two formulations with known or suspected systemic fungicidal activity were tested for efficacy as seed treatments against dwarf bunt at Logan and Blue Creek, UT, Preston, ID, and Kalispell, MT, during the 5-yr period 1976–1980. These included: benomyl, 50% (Benlate) (E. I. du Pont de Nemours & Co.); benodanil, 50% (BASF 317F) (BASF Wyandotte Corp.); carbendazim, 15% + maneb, 60% (DPX-14) (E. I. du Pont de Nemours & Co.); carboxin, 75% (Vitavax) (UniRoyal, Inc.); CGA-39896, 25% (experimental fungicide) and etaconazole, 21.5% (CGA-64251) (CIBA-Geigy Corp.); fenapanil, 36%, 24.2% (RH 2161) (Rohm & Haas Co.); fenarimol, 12.5% (EL-222) (Eli Lilly & Co.); methfuroxam, 75%, 6.2% (H-719, UBI-1160), methfuroxam, 5% + thiram, 25.8% (UBI-1194), and methfuroxam, 12.5% + zinc ion-maneb complex, 62.5% (UBI-1159) (UniRoyal, Inc.); nuarimol, 70%, 9.5% (EL-228) (Eli Lilly & Co.); thiabendazole, 60%, 42%, 30% (Mertect 360, Mertect 140, Mertect LSP) (Merck & Co., Inc.); triadimefon, 25% (BAY-MEB 6447) (Bayleton) and triadimenol, 25%, 14% (BAY-KWG 0519) (Baytan) (Mobay Chemical Corp.); and triazbutil, 70% (RH-124) (Indar) (Rohm & Haas Co.).

The chemicals were applied to 200-g units of seed of the dwarf bunt-susceptible wheat cultivar Wanser at several rates by using the procedure described previously (7). Individual plots consisted of single rows 1.5 m long and 45 cm apart. Treatment replicates varied from two to four, depending on the year and location. The plots were artificially inoculated with *T. controversa* teliospores collected from the area in which each nursery was located. The teliospores were applied as an aqueous suspension with a hand sprayer at the rate of 0.5 g per row to the surfaces of the rows after seeding or after seedling emergence. The seed was planted shallow (1–2 cm) in deep furrows and a vermiculite cover (5–7 cm) was used to enhance infection at Logan in years when snow cover was lacking (1). Infection data were recorded as the percentage of bunted heads at maturity.

During 1979 and 1980, the possibility of increasing fungicide uptake and/or effectiveness by adding certain solvent carriers (water, acetone, DMSO, and ethylene glycol) was investigated. A preliminary study (S. M. Rine, *unpublished*) to determine possible adverse effects of these solvents on wheat seed germination ruled out the use of ethylene glycol. It also indicated that a 100% concentration of acetone and a 10% concentration of DMSO could be used safely. Seed was soaked in solvent-fungicide combinations for 15 min in 1979 and for 60 min in 1980 before drying and planting. The standard slurry method of treatment served as the control.

To examine the influence of the date of seeding on seed-treatment effectiveness, early, medium, and late plantings were made in the fall of 1976 and 1978. The systemic fungicides benomyl, methfuroxam, and two thiabendazole formulations (Mertect 360 in 1976 and Mertect LSP in 1978) were applied to seed at rates of 2.1, 4.2, and 8.3 g a.i./kg, respectively. Tests were conducted at Blue Creek, UT, and Preston, ID, in 1976 and at Logan and Blue Creek, UT, and at Preston, ID, in 1978. Plot size, methods of inoculation, and data collection were the same as described.

Table 2. Effect of different solvents on the efficacy of systemic fungicide seed treatments in controlling dwarf bunt (*Tilletia controversa*) of wheat

Solvent	Mean percent dwarf bunt	
	1979[a]	1980[b]
Water	30.8	10.5
10% DMSO	32.0	10.8
Acetone	32.5	10.1
Slurry check	28.8	12.0

[a] Each figure is the average of 135 observations (three locations × three replicates × 15 fungicide-rate combinations).

[b] Each figure is the average of 216 observations (three locations × three replicates × 24 fungicide-rate combinations).

RESULTS AND DISCUSSION

Incidence of dwarf bunt in the untreated check plots varied considerably from year to year and from location to location (Table 1). Nevertheless, infection levels were adequate to provide meaningful data except in 1977 at all locations and in 1979 at Blue Creek. Infection percentages for check plots, averaged among locations for 1976, 1978, 1979, and 1980, were 71, 57, 59, and 28, respectively. Inasmuch as treatments and rates were not the same in all years, and infection levels varied from year to year and from location to location, the data (Table 1) were not always cross-comparable. Relative comparisons can be made, however, by relating the treatments to the untreated control.

Many of the formulations tested showed at least some degree of dwarf bunt control, particularly at the higher rates of application. But practical control, eg, less than 10% infection, was attained by relatively few. The most effective materials were those containing thiabendazole, triadimenol, or etaconazole.

Inconsistent control from location to location and from year to year and adverse effects on stands and vigor were problems that were common in varying degrees for compounds that exhibited the greatest control potential. In 1978, for example, dwarf bunt control, even at the highest rates of the most effective fungicides, was marginal. Location × fungicide interactions were also highly significant ($P = 0.01$) each year. Much of the observed variability in bunt control can probably be explained by differences in fall growing conditions. These factors affect the amount of plant growth and, consequently, the concentration of the fungicide in the plant tissues when infection takes place in midwinter.

Etaconazole was especially detrimental to stands and seedling vigor when used at rates high enough to control dwarf bunt. These adverse effects were less pronounced with thiabendazole and triadimenol but were still present to a degree. Of the compounds tested, thiabendazole (Mertect LSP) exhibited the best overall combination of dwarf bunt control with minimal adverse effects. Further testing, however, may show triadimenol to be equally effective.

It was hoped that the addition of a solvent-carrier might increase the amount of fungicide absorbed by the wheat seed (Table 2). This could be important because seed treatment and planting precede dwarf bunt infection by several months (6,11), and considerable dilution of the fungicide probably occurs as plant growth increases during this interim period. The solvents tested failed to enhance fungicide effectiveness when compared with the standard slurry method of applying the seed treatments (Table 2). Sampling of potential solvent-carriers was limited, however, and others may merit investigation.

Of the fungicides tested in the date-of-seeding trials, only the thiabendazole formulations (Mertect 360 and Mertect LSP) effectively reduced dwarf bunt infection (Table 3). Consequently, the data and conclusions relative to the effect of planting date are limited to these two formulations. Three major conclusions were drawn from the results (Table 3): 1) the medium planting date (1 October) was the most favorable for dwarf bunt infection, 2) fungicide effectiveness generally increased with late planting, and 3) the higher rates of treatment were required for adequate dwarf bunt control.

Results reported previously (5) also indicated an increase in effectiveness of thiabendazole seed treatment for dwarf bunt control with late seeding. The reduced effectiveness of thiabendazole, and probably systemic fungicides in general, in the early plantings can probably be attributed to greater plant growth, which results in greater dilution

Table 3. Influence of planting date on the effectiveness of thiabendazole as a seed treatment for control of dwarf bunt (*Tilletia controversa*)

Year tested and trade name of formulation	Rate (g a.i./kg)	Mean percent dwarf bunt[a]								
		Logan, UT			Blue Creek, UT			Preston, ID		
		15 Sept.	1 Oct.	15 Oct.	15 Sept.	1 Oct.	15 Oct.	15 Sept.	1 Oct.	15 Oct.
1976										
Untreated check	0.0	...	...	...	86	93	86	76	79	63
Mertect 360[b]	2.1	...	...	...	21	40	12	48	49	34
Mertect 360	4.2	...	...	...	16	16	7	9	11	7
Mertect 360	8.3	...	...	...	8	7	1	1	3	3
LSD ($P = 0.05$) = 19%										
1978										
Untreated check	0.0	7	55	40	56	62	69	50	93	47
Mertect LSP[b]	2.2	7	29	4	53	36	19	24	25	7
Mertect LSP	4.3	6	12	1	40	17	4	8	11	1
Mertect LSP	8.7	5	6	1	36	7	1	5	4	0
LSD ($P = 0.05$) = 17%										

[a] Average of three replicates.

[b] Mertect 360 is a 60% a.i. wettable powder; Mertect LSP is a 30% a.i. flowable formulation.

of the fungicide within the plant by the time infection occurs in midwinter. Early-sown wheat also has a longer time to tie up or break down the fungicide within the plant before the infection period. The higher rates of application probably result in better control by compensating somewhat for the dilution effect of plant growth. Although late planting may enhance the control of dwarf bunt by seed treatment fungicides, it is not likely that this practice will find general use. Late planting of winter wheat almost always results in lower yields, so the advantage of greater dwarf bunt control must be weighed against this potential reduction in yield.

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