Systemic Fungicides for Control of Dwarf Bunt of Wheat: II. Foliar Application

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ABSTRACT

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Twenty-one fungicide formulations were applied as fall or spring foliar sprays to the dwarf bunt-susceptible winter wheat (*Triticum aestivum*) cultivar Wanser during the 7-yr period 1975–1981. Several contact-type fungicides, as well as some systemic compounds, controlled dwarf bunt when applied as fall sprays. It is suspected that most, but not all, of the control from fall applications of the systemic fungicides resulted from direct action against teliospores of *Tilletia controversa* at or near the soil surface. In most years and with most fungicides, spring foliar applications were ineffective in controlling dwarf bunt. Etaconazole, however, significantly reduced infection in 3 of the 4 yr it was tested and provided the first indication that the dwarf bunt fungus can be eradicated once it has become established in the wheat plant.

The standard seed treatments that are effective against common bunt of wheat (*Triticum aestivum* L.), incited by *Tilletia caries* (DC.) Tul. and *T. foetida* (Wallr.) Liro, have failed to control dwarf bunt caused by *T. controversa* Kühn (5,6,10,14). This is because of basic differences between the common and dwarf bunt fungi in requirements for teliospore germination (3,12,13), in relative longevity of teliospores in the soil (1,11), and in the site and timing of infection (8,18–20). Inasmuch as most dwarf bunt infection occurs in midwinter (8,19) after seedling emergence and development, it could be expected that seed treatments would be ineffective against *T. controversa*. This is particularly true for contact-type fungicides whose activity is primarily limited to the seed surface or to the soil in close proximity.

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Because of their potential for conferring protection to wheat plants over an extended period of time, systemic fungicides have attracted the attention of wheat researchers in areas where dwarf bunt is a problem. Seed treatment is the simplest and most economical means of applying systemic fungicides, and some degree of dwarf bunt control has been reported with this method (2,4,7). Because of the extended period between planting and infection, however, control by seed treatment has been erratic (7). One possible way to circumvent or minimize the dilution and/or breakdown of a systemic fungicide with time and plant growth would be to apply the fungicide to the foliage in the fall, just before the infection period. Another possibility would be to apply systemic fungicide sprays in spring to eradicate the dwarf bunt fungus in plants already infected.

An effective spring-applied foliar spray would have certain advantages over seed treatments or fall sprays. The incidence of dwarf bunt is greatly influenced by winter weather conditions (1,8,19). An open winter usually results in very little dwarf bunt, whereas persistent snow cover favors dwarf bunt development. Dwarf bunt symptoms in wheat, eg, leaf flecking and streaking, can be discerned visually by a trained observer shortly after growth resumes in the spring. By waiting until spring, when the extent of infection can be determined, an informed decision could be made as to whether or not fungicide treatment is needed. In years when winter conditions are not conducive to infection and symptoms are not visible in the spring, the expense and potential environmental problems associated with fungicide treatment could be avoided.

The purpose of this study was to examine systemic fungicides as foliar sprays for their potential in controlling dwarf bunt.

MATERIALS AND METHODS

Twenty-one fungicide formulations (as foliar sprays) were tested for their effectiveness in controlling dwarf bunt over the 7-yr period 1975–1981. These included: benomyl, 50%, (Benlate) E. I. du Pont de Nemours & Co.); benodanil, 50%, (BASF-317F) (BASF Wyandotte Corp.); CGA-39896, 25% (experimental fungicide) (CIBA-Geigy Corp.); carboxin, 75% (Vitavax) (UniRoyal, Inc.); 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.); hexachlorobenzene, 40% (Anticarie) (H. P. Rossinger); maneb, 80%, (Vancide) (R. T. Vanderbilt); methfuroxam, 6.2%, (UBI-1160) and methfuroxam, 75% (H-719) (UniRoyal, Inc.); nuarimol, 9.5% (EL-228) (Eli Lilly & Co.); PCNB, 75% (Terraclor) (Olin Corp.); thiabendazole, 60%, 30% (Mertect 360, Mertect LSP) (Merck & Co., Inc.); thiram, 75% (Arasan) (E. I. du Pont de Nemours & Co.); triadimefon, 25% (BAY-MEB 6447) (Bayleton) and triadimenol, 25%, 14% (BAY-KWG 0519) (Baytan) (Mobay Chemical Corp.); and triazbutyl, 70% (RH-124) (Indar) (Rohm & Haas Co.).

Fall spray studies. Foliar applications of systemic fungicides were made to artificially inoculated rows of Wanser wheat at Logan, UT, in the fall of 1975 and 1977. Details of the planting and inoculation procedures are described in a previous report (9).

In 1975, 14 chemicals were applied at three rates as foliar sprays on 10 December. At this time, the wheat plants were 3–5 cm tall, in the two-leaf stage, and growth had essentially ceased for the winter. The fungicides were applied in a band that extended about 7.5 cm on either side of the plants. Water, at the rate of 187 L/ha (20 gallons per acre), was used as the carrier. Each treatment was replicated three times. The chemicals and rates used are shown in Table 1.

In 1977, six fungicides were applied at three rates on two dates, 3 and 30 November (Table 2). Plants at the first date were at the two-leaf stage, 3–5 cm tall. At the second spraying date, plants were in the three-leaf stage, about 7–9 cm tall, and had ceased active growth. Application procedures were similar to those used in the 1975 test. Infection data were recorded as percent bunted heads at maturity.

Spring spray studies. Systemic fungicides were applied as spring foliar sprays to dwarf bunt-infected plants of cultivar Wanser in 1975, 1976, and 1978–1981. The trials were grown under artificially inoculated conditions at Logan. Individual plots consisted of single 1.5-m rows. Various surfactants, Tronic and X-77 (Kalo Agricultural Chemicals, Inc.) glycerol, and DMSO, were added to the spray treatments during the first 3 yr in an attempt to enhance absorption of the fungicides. Surfactants were not used in the 1979–1981 tests because of the apparent lack of effect in the earlier trials. The spray treatments were applied at three dates (early, middle, and late spring) in 1975 and at two dates (early and middle-spring) in 1976. Since there was no apparent effect attributed to spray date, only one date of spraying (early spring) was used in subsequent years.

Table 1. Incidence of dwarf bunt in Wanser wheat treated with foliar-applied fungicides in the fall of 1975

	Mean percent dwarf bunt at kg a.i./ha (applied 10 Dec.)[b]			
Fungicide and formulation[a]	**0**	**1.12**	**2.24**	**4.48**
Benomyl 50W	82	53	31	15
CGA-39896 25W	89	38	4	0
Carboxin 75W	85	84	65	56
Fenapanil 36L	75	62	54	49
Fenarimol 12.5L	88	82	75	63
Hexachlorobenzene 40W	86	49	30	13
Maneb 80W	84	64	40	23
Methfuroxam 75W	89	46	12	1
Methfuroxam 6.2F	80	58	36	8
PCNB 75W	88	82	40	29
Thiabendazole 60W	83	63	42	19
Thiram 75W	89	76	55	53
Triadimefon 25W	82	71	64	24
Triazbutyl 70L	81	79	83	81
LSD ($P = 0.05$) = 23[c]				

[a] Percentage of active ingredient and formulation type (W = wettable powder, L = liquid, and F = flowable).
[b] Average of three replicates
[c] Applies to comparisons of rates within a fungicide and to fungicides within a rate.

Table 2. Incidence of dwarf bunt in Wanser wheat treated with foliar-applied fungicides in the fall of 1977

		Mean percent dwarf bunt[b]	
Fungicide and formulation[a]	**Rate (kg a.i./ha)**	**Sprayed 3 Nov.**	**Sprayed 30 Nov.**
Check	···	69	69
Benomyl 50W	1.12	4	2
	2.24	1	1
	4.48	1	1
Etaconazole 21.5W	1.12	4	27
	2.24	1	2
	4.48	1	1
Hexachlorobenzene 40W	1.12	15	5
	2.24	2	2
	4.48	1	1
Methfuroxam 75W	1.12	60	56
	2.24	55	33
	4.48	52	20
Thiabendazole 30F	1.12	45	27
	2.24	22	8
	4.48	12	1
Triadimenol 14F	1.12	39	24
	2.24	13	4
	4.48	10	1
LSD ($P = 0.05$) = 7[c]			

[a] Percentage of active ingredient and formulation type (W = wettable and F = flowable).
[b] Average of three replicates.
[c] Applies to comparisons of rates within a fungicide and to fungicides within a rate.

RESULTS AND DISCUSSION

Fall spray studies. Most of the fungicides tested in the 1975 fall spray study reduced dwarf bunt significantly ($P < 0.05$), particularly at the higher application rates (Table 1). The fact that several of the nonsystemic compounds, eg, PCNB, hexachlorobenzene, and maneb, reduced dwarf bunt indicates that part, if not all, of the control resulted from a direct action against teliospores of the dwarf bunt pathogen at the soil surface rather than from absorption and translocation of the fungicide. Past studies have demonstrated the effectiveness of contact fungicides like hexachlorobenzene and PCNB against dwarf bunt when used as soil-applied dusts or drenches (5,10,14–17,21). The highest levels of control in our 1975 study, however, were achieved by several of the systemic materials, eg, methfuroxam (H-719) and CGA-39896, which possibly indicates at least a degree of control through fungicide absorption. It does not rule out the possibility, however, that

Table 3. Percent dwarf bunt in Wanser wheat treated with spring foliar applications of etaconazole

Rate (kg a.i./ha)	Mean percent dwarf bunt[a]			
	1978	1979	1980	1981
0.0	81.2	51.7	31.0	95.3
1.12	···	···	···	87.3
2.24	67.4	48.8	···	75.0
2.80	···	···	10.8	···
4.48	60.1	47.5	···	51.7
5.60	···	···	5.3	···
8.96	53.3	45.8	···	35.8
11.20	···	···	4.0	···
17.92	···	···	···	25.0
LSD ($P = 0.05$)	9.7	NS	3.8	8.0

[a]Average of six replicates.

most of the action of the systemic fungicides may also have been against teliospores at the soil surface.

The 1977 study involved two application dates and provided additional evidence that uptake and translocation of systemic fungicides may have contributed to the degree of dwarf bunt control (Table 2). The only nonsystemic fungicide tested, hexachlorobenzene, was as effective in the early application as it was in the later one (except at the 1.12 kg/ha rate). This would be expected if control were entirely attributed to fungicidal action in the soil around the plants. In contrast, several of the systemic fungicides, especially triadimenol and thiabendazole, were considerably more effective at the later application, which indicates that part of their effectiveness was due to absorption, inasmuch as a fungicide applied and absorbed in late fall would probably be present in greater concentrations and would consequently provide greater protection at the time of infection (midwinter) than would the same fungicide applied earlier. Hoffmann (6) earlier reported some degree of dwarf bunt control after fall spray applications of the systemic fungicides benomyl and carboxin.

Spring spray studies. No dwarf bunt control was obtained with the spring foliar sprays tested in 1975 and 1976. Etaconazole was added to the test group in 1978 and resulted in statistically significant ($P < 0.05$), but practically unacceptable, reductions in dwarf bunt at all three rates tested (2.24, 4.48, and 8.96 kg a.i./ha) (Table 3). None of the formulations used in 1979 achieved significant control, although dwarf bunt reduction in response to the etaconazole treatments approached significance ($P > 0.05$). The 1980 data provided the first indication that dwarf bunt might be reduced to a practical level through spring foliar sprays. Etaconazole at either 5.6 or 11.2 kg a.i./ha produced both a significant and a practical reduction in infection (Table 3). Similar results were obtained in 1981 at 4.48, 8.96, and 17.92 kg a.i./ha rates. Surprisingly, very little phytotoxicity was observed with foliar applications of etaconazole, even at the higher rates. Some leaf flecking and tip burning were noted, but these disappeared within 3–4 wk, and at maturity, stands and yields appeared unaffected. This is quite a contrast with the drastic effects on stands and seedling vigor that we observed when using etaconazole as a seed treatment (9). One interesting side effect of the foliar applications with this compound was a marked reduction in plant height and a darker green coloration of the foliage. Except for moderate to severe leaf burning by benodanil, phytotoxicity was not a serious problem with the compounds used in the foliar application studies.

The economic and environmental considerations involved in applying fungicides at the rates required to control dwarf bunt in these foliar spray studies are probably prohibitive. Our initial objective, however, was to determine whether or not it is possible to eradicate the dwarf bunt fungus once it has become established in the wheat plant. Although complete eradication was not attained, significant ($P < 0.05$) reductions in infection were achieved. Further refinements in fungicides, rates, and application procedures might eventually bring foliar spraying for dwarf bunt control into the range of economic feasibility.

LITERATURE CITED

1. Baylis, R. J. 1958. Studies of *Tilletia controversa*, the cause of bunt of winter wheat. Can. J. Bot. 36:17-32.
2. Dewey, W. G., and Albrechtsen, R. S. 1974. Effect of thiabendazole seed treatment on the incidence of dwarf bunt and on the yield of winter wheat. Plant Dis. Rep. 58:743-745.
3. Dewey, W. G., and Tyler, L. J. 1958. Germination studies with spores of the dwarf bunt fungus. Phytopathology 48:579-580.
4. Dickens, L. E., and Oshima, N. 1971. Chemotherapeutants evaluated for control of dwarf bunt of wheat. Plant Dis. Rep. 55:613-614.
5. Fushtey, S. G. 1961. Studies on the control of dwarf bunt in winter wheat. Can. J. Plant Sci. 41:568-577.
6. Hoffmann, J. A. 1971. Control of common and dwarf bunt of wheat with systemic fungicides. Plant Dis. Rep. 55:1130-1135.
7. Hoffmann, J. A. 1971. Control of common and dwarf bunt by seed treatment with thiabendazole. Phytopathology 61:1071-1074.
8. Hoffmann, J. A., and Purdy, L. H. 1967. Effect of stage of development of winter wheat on infection by *Tilletia controversa*. Phytopathology 57:410-413.
9. 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 Dis. 67:294-297.
10. Holton, C. S., and Jackson, T. L. 1952. Results from tests for the control of dwarf bunt by applying fungicides to infested soil. Plant Dis. Rep. 36:423.
11. Holton, C. S., Bamberg, R. H., and Woodward, R. W. 1949. Progress in the study of dwarf bunt of winter wheat in the Pacific Northwest. Phytopathology 39:986-1000.
12. Lowther, C. V. 1948. Low temperature as a factor in the germination of dwarf bunt chlamydospores. Phytopathology 38:309-310.
13. Meiners, J. P., and Waldher, J. T. 1959. Factors affecting spore germination of twelve species of *Tilletia* from cereals and grasses. Phytopathology 49:724-728.
14. Purdy, L. H. 1957. Differential response of dwarf bunt to seed and soil surface treatment with hexachlorobenzene. Plant Dis. Rep. 41:916-918.
15. Purdy, L. H. 1959. Residual activity of three fungicides applied to the soil for bunt control. Plant Dis. Rep. 43:9-11.
16. Purdy, L. H. 1963. Wheat dwarf bunt control by aerial application of hexachlorobenzene. Plant Dis. Rep. 47:5-6.
17. Purdy, L. H. 1965. Common and dwarf bunts, their chemical control in the Pacific Northwest. Plant Dis. Rep. 49:42-46.
18. Purdy, L. H., Hoffmann, J. A., Meiners, J. P., and Stewart, V. R. 1963. Time of year of infection of winter wheat by the dwarf bunt fungus. Phytopathology 53:1419-1421.
19. Purdy, L. H., Kendrick, E. L., Hoffmann, J. A., and Holton, C. S. 1963. Dwarf bunt of wheat. Ann. Rev. Microbiol. 17:199-222.
20. Tyler, L. J. 1958. Protracted period of vulnerability of winter wheat to attack by *Tilletia controversa*. Plant Dis. Rep. 42:1387-1390.
21. Tyler, L. J., and Jensen, N. F. 1963. Soil application of hexachlorobenzene and copper oxychloride for control of dwarf bunt. Plant Dis. Rep. 47:197-199.