Chemical Seed Treatments for Controlling Seedborne and Soilborne Common Bunt of Wheat

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ABSTRACT

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During a 10-yr period (1969–1978), 51 different chemical formulations were tested as seed treatments for the control of seedborne and soilborne common bunt of wheat. Formulations that controlled both seedborne and soilborne bunt at practical rates were those that contained carboxin, CGA-64251, fenapanil, hexachlorobenzene, methfuroxam, nuarimol, pentachloronitrobenzene (PCNB), thiabendazoles, triadimefon, or triadimenol. Formulations containing benomyl, chloroneb, fuberidazole, maneb, pyracarbolid, TCMTB, or zinc ion–maneb complex were effective against seedborne but not soilborne bunt. CGA-64251, methfuroxam, and triadimenol appear to be more potent against bunt than hexachlorobenzene.

Additional key words: fungicides, *Tilletia caries*

Common bunt, caused by *Tilletia caries* (DC.) Tul. and *T. foetida* (Wallr.) Liro, is potentially one of the most destructive diseases of wheat (*Triticum aestivum* L.). Throughout much of the developed world, the disease is controlled by chemical seed treatment. This practice has become so accepted that seemingly little effort is being directed toward control by resistant cultivars or other measures.

Control of common bunt in the Pacific Northwest of the United States is complicated by the infectivity of soilborne spores, which are not controlled by some seed-treatment chemicals that are effective against seedborne inoculum. Consequently, common bunt remained a major production problem of wheat in the Pacific Northwest until about 1956, when the effectiveness of hexachlorobenzene against both seedborne and soilborne inoculum was conclusively demonstrated (14,20). Since then, diligent use of this chemical has reduced losses from common bunt to insignificance.

Of the seed-treatment materials now registered for use on wheat, only four are effective against both seedborne and soilborne common bunt: hexachlorobenzene, pentachloronitrobenzene (PCNB), carboxin, and thiabendazole. Hexachlorobenzene, a nonproprietary material with recognized environmental hazards (8,9), is gradually being withdrawn from use. PCNB is currently under review by the Environmental Protection Agency, and its use may be restricted. Most carboxin formulations used commercially as seed treatments on wheat contain insufficient active ingredient to adequately control soilborne bunt (12). Thiabendazole, currently registered for use on wheat in five northwestern states only, may be too costly to be used except in areas where dwarf bunt (*T. controversa* Kuehn) is a serious problem. Moreover, strains of *T. foetida* tolerant to hexachlorobenzene and PCNB have developed in Australia (17) and Greece (21), and conflicting reports (7,16) suggest that both *T. foetida*

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This article reports research involving pesticides and does not contain recommendations for their use. All uses of pesticides must be registered by appropriate state and/or federal agencies before they can be recommended.

Table 1. Effectiveness of fungicides as seed treatments for control of seedborne and soilborne common bunt (*Tilletia caries*) at Pendleton, Oregon, and Pullman, Washington, during 1969–1978

		Mean percentage common bunt				
		Seedborne		Seedborne and soilborne		
Fungicide and formulation[a]	Rate (g or ml/kg)	Pendleton	Pullman	Pendleton	Pullman	Years tested
Untreated checks						
Uninoculated seed	...	1	1	79	80	10
Inoculated seed	...	89	83	88	88	10
Treated checks						
Hexachlorobenzene 40W	1.0	1	1	6	6	10
Hexachlorobenzene 40W	2.1	1	1	4	6	10
Cyano (methylmercuri) guanidine 2.2L	0.5	1	2	68	68	10
Cyano (methylmercuri) guanidine 2.2L	0.8	1	1	61	70	10
Benomyl 50W	1.0	4	28	48	68	1
Benomyl 50W	2.1	14	17	45	67	5
Benomyl 50W	4.2	9	4	31	41	5
Benomyl 50W	8.3	0	0	2	1	1
Benomyl 50W	10.4	0	0	1	1	1
Captan 50W	2.1	80	86	95	88	2
Captan 50W	4.2	65	72	94	85	1
Carbendazim + maneb 15+60W	2.1	56	59	80	80	2
Carbendazim + maneb 15+60W	4.2	18	24	74	76	2
Carboxin 75W	1.0	2	12	22	40	1
Carboxin 75W	2.1	1	2	10	33	3
Carboxin 75W	4.2	0	1	2	4	2
Carboxin 75W	8.3	0	0	0	10	1
Carboxin 75W	10.4	0	0	0	2	1
Carboxin 34F	1.6	1	6	42	18	1
Carboxin 34F	3.3	0	0	32	8	1
Carboxin 34F	6.5	0	0	2	1	1
Carboxin + captan 37.5+37.5W	3.1	0	0	8	2	1
Carboxin + thiram 37.5+37.5W	3.1	0	0	9	4	1
Carboxin + thiram 17+17F	1.3	12	18	82	80	1
Carboxin + thiram 17+17F	2.0	13	15	70	85	1
Carboxin + thiram 17+17F	2.6	8	12	59	72	2
Carboxin + thiram 17+17F	3.3	0	0	70	48	1
Carboxin + thiram 17+17F	6.5	0	0	22	6	1

(*continued on next page*)

Table 1. (*continued from preceding page*)

Fungicide and formulation[a]	Rate (g or ml/kg)	Mean percentage common bunt: Seedborne Pendleton	Seedborne Pullman	Seedborne and soilborne Pendleton	Seedborne and soilborne Pullman	Years tested
Carboxin + thiram 17+17F	13.0	0	0	0	0	1
CGA-64251 21.5W	0.6	0	2	0	2	1
CGA-64251 21.5W	1.2	0	0	0	6	1
CGA-64251 21.5W	2.5	0 (PS)[b]	0 (PS)	0 (PS)	2 (PS)	1
Chloranil 95W	2.1	12	20	68	58	1
Chlorine dioxide 2L	1.1	90	90	92	92	1
Chlorine dioxide 2L	2.2	90	92	92	92	1
Chlorine dioxide 2W	2.1	95	90	97	96	1
Chlorine dioxide 2W	4.2	94	90	96	94	1
Chloroneb 65W	2.1	38	11	41	63	1
Chloroneb 65W	4.2	4	3	18	40	1
Copper carbonate 5L	1.1	85	90	98	95	1
Copper carbonate 5L	2.2	72	78	96	85	1
Dicloran 75W	2.1	64	25	82	80	1
Dicloran 75W	4.2	30	46	69	72	1
Fenapanil 36EC	0.3	82	88	85	90	1
Fenapanil 36EC	0.7	63	68	78	72	2
Fenapanil 36EC	1.3	12	6	28	11	2
Fenapanil 36EC	2.6	0	0	0	1	1
Fenapanil 24.2EC	1.3	1	2	45	48	1
Fenapanil 24.2EC	2.7	0	2	1	2	1
Fenapanil 24.2EC	5.4	0	1	0	6	1
Fenarimol 12.5L	1.1	58	55	78	72	1
Fenarimol 12.5L	2.2	38	22	65 (PS)	50 (PS)	1
Fenarimol 12.5L	4.3	6 (PS)	2 (PS)	22 (PS)	12 (PS)	1
Fuberidazole 50W	2.1	40	6	61	46	1
Fuberidazole 50W	4.2	2	0	28	22	1
Hexachlorobenzene + captan 18+18F	1.6	0	1	2	8	1
Hexachlorobenzene + captan 18+18F	2.2	0	0	8	8	1
Hexachlorobenzene + maneb 5+25L	2.7	10	8	60	62	1
Hexachlorobenzene + maneb 5+25L	4.3	0	0	20	11	1
Hexachlorobenzene + captan + maneb 20+20+15D	1.0	2	3	10	2	1
Hexachlorobenzene + captan + maneb 20+20+15D	2.1	2	0	1	2	1
Maneb 50D	2.1	18	42	78	96	1
Maneb 50D	3.1	4	6	85	82	1
Maneb 50D	4.2	0	8	60	78	1
Maneb 50D	6.3	0	0	82	78	1
Maneb + lindane 50+18.7D	2.1	14	58	78	94	1
Maneb + lindane 50+18.7D	4.2	4	18	72	92	1
Metalaxyl 50W	0.6	92	88	95	96	1
Metalaxyl 50W	1.2	96	90	94	96	1
Metalaxyl 50W	2.5	98	92	98	96	1
Methfuroxam 75W	0.16	80	88	68	88	1
Methfuroxam 75W	0.3	0	1	4	8	2
Methfuroxam 75W	0.6	1	0	0	1	2
Methfuroxam 6F	0.7	75	55	68	72	1
Methfuroxam 6F	1.3	2	8	38	10	1
Methfuroxam 6F	2.6	0	1	1	2	1
Methfuroxam 6F	5.4	0	1	2	0	2
Methfuroxam 6F	10.9	1	0	0	0	2
Methfuroxam 4.2D	1.9	82	78	85	80	1
Methfuroxam 4.2D	3.8	1	2	20	45	1
Methfuroxam + thiram 5.0+25.8F	0.7	35	36	69	75	2
Methfuroxam + thiram 5.0+25.8F	1.3	4	5	40	51	2
Methfuroxam + thiram 5.0+25.8F	2.6	0	0	1	5	3
Methfuroxam + zinc ion–maneb complex 12.5+62.5W	2.1	2	1	1	0	1
Methfuroxam + zinc ion–maneb complex 12.5+62.5W	4.2	0	0	2	0	1
Methfuroxam + zinc ion–maneb complex 12.5+62.5W	8.3	0	0	0	0	1
Metiram 53D	4.2	48	42	82	80	1
Metiram 53D	6.3	35	4	75	88	1
Nuarimol 9.5L	1.1	0	2	1	6	1
Nuarimol 9.5L	2.2	0	0	1	3	1
Nuarimol 9.5L	4.3	0 (PS)	0 (PS)	0 (PS)	0 (PS)	1
Octhilinone 90EC	1.1	72	72	82	85	1
Octhilinone 90EC	2.2	42	28	80	85	1

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and *T. caries* may develop strains tolerant to carboxin. Thus, the continued use or effectiveness of registered seed-treatment chemicals that control both seedborne and soilborne common bunt is highly problematic.

Although several reports on the effectiveness of seed-treatment chemicals for controlling seedborne common bunt have appeared in recent years (1–6, 10,11,19), it appears that little work is being done to evaluate new fungicides for control of soilborne bunt.

For these reasons, evaluation of fungicides as seed treatments for controlling both forms of common bunt have been continued in the Pacific Northwest. We summarize here the results of these investigations over a 10-yr period from 1969 through 1978.

MATERIALS AND METHODS

The winter wheat cultivar Orin (CI 12687) was used in all tests. The seed was inoculated with dry teliospores of *T. caries* (race T-16) at the rate of 5 g of teliospores per kilogram of seed. In the soilborne bunt tests, the soil was inoculated by spraying a water suspension of teliospores (*T. caries*, race T-16) in open furrows at the rate of 0.5 g of teliospores per 1.5 m of row immediately before seeding.

The seed was treated with fungicides in units of 100 g (200 g with liquid formulations that could not be diluted with water). Liquid formulations that were miscible with water were applied as 1:4 dilutions (v/v) with water. Wettable powders and flowable formulations were mixed with appropriate amounts of water and applied as slurries. Dust formulations were applied directly to the seed as dry powders. The theoretical weight or volume of fungicide formulations per unit of seed was increased by 10% to compensate for loss of the fungicide during treatment. Application rates of flowable formulations were calculated on the basis of weight rather than volume.

The appropriate amount of slurry, liquid, or dust was placed in a 500-ml Erlenmeyer flask. The flask was rotated to spread the fungicide over the inner wall of the flask. The unit of seed was added, and the flask was rotated and shaken vigorously until all visible moisture and fungicide were removed from the inner wall. After treatment, the seed was first placed in paper bags and then dispensed into seed envelopes before planting.

The seed was planted by hand in furrows 1.5 m long and covered to a depth of 5–8 cm. About 100 seeds were planted in each 1.5-m row. Two replicates of each treatment were planted in mid- to late-October at Pendleton, Oregon, and Pullman, Washington. The effectiveness of the treatments was measured in terms of bunt percentages based on counts of bunted heads and total number of heads per row when the plants matured the

Table 1. (*continued from preceding page*)

Fungicide and formulation[a]	Rate (g or ml/kg)	Mean percentage common bunt: Seedborne Pendleton	Seedborne Pullman	Seedborne and soilborne Pendleton	Seedborne and soilborne Pullman	Years tested
Oxycarboxin 75W	2.1	60	48	68	86	1
Oxycarboxin 75W	4.2	48	18	68	82	1
PCNB 75W	1.0	1	5	16	28	2
PCNB 75W	2.1	0	1	5	11	3
PCNB 24EC	2.2	38	6	42	7	2
PCNB 24EC	4.3	7	1	8	5	2
PCNB 24L	2.2	0	1	3	5	3
PCNB 24L	4.3	0	0	1	4	2
PCNB 24L	8.7	0	0	1	2	1
PCNB + ethazol 23.2+5.8L	2.2	4	1	11	4	3
PCNB + ethazol 23.2+5.8L	4.3	0	0	0	2	1
PCNB + ethazol 23.2+5.8L	8.7	0	0	1	4	1
PCNB + ethazol 22.8+11.4L	2.2	2	4	16	23	2
PCNB + ethazol 22.8+11.4L	4.3	1	2	11	14	2
PCNB + ethazol 22.8+11.4L	6.5	0	1	2	2	2
Phenylmercuric ammonium acetate 3.5L	0.5	16	16	17	78	2
Phenylmercuric ammonium acetate 3.5L	0.8	0	2	88	65	1
Phenylmercuric ammonium acetate 3.5L	1.1	8	9	75	75	1
Pyracarbolid 50W	2.1	15	24	50	85	2
Pyracarbolid 50W	4.2	2	2	6	29	2
TCMTB 60EC	0.5	2	6	74	75	2
TCMTB 60EC	0.8	3	14	75	98	1
TCMTB 60EC	1.1	1	8	63	54	2
TCMTB 30EC	0.8	9	11	90	82	1
TCMTB 30EC	1.1	10	6	84	82	2
TCMTB 30EC	1.6	2	2	95	68	1
TCMTB 30EC	2.2	2	0	72	88	1
Thiabendazole 60W	1.0	2	4	23	30	4
Thiabendazole 60W	2.1	0	1	12	11	6
Thiabendazole 60W	4.2	0	0	1	5	5
Thiabendazole 42F	1.1	4	11	18	38	2
Thiabendazole 42F	2.2	1	4	10	24	2
Thiabendazole 42F	4.3	0	0	1	0	1
Thiabendazole 30F	1.1	36	32	45	32	2
Thiabendazole 30F	2.2	5	6	18	14	2
Thiabendazole 30F	4.3	1	1	8	11	2
Thiophanate-methyl 70W	4.2	48	55	72	78	1
Thiram 65W	2.1	48	50	88	88	1
Thiram 65W	4.2	32	40	85	75	1
Triadimefon 25W	1.0	0	2	20	28	3
Triadimefon 25W	2.1	0	1	0	2	3
Triadimefon 25W	4.2	0	0	0	1	1
Triadimenol 25W	0.5	0	1	0	3	1
Triadimenol 25W	1.0	0	0	0	2	1
Triadimenol 25W	2.1	0	0	0	0	1
Triazbutil 80W	1.0	38	35	90	80	1
Triazbutil 80W	3.1	10	4	68	78	1
Zinc ion–maneb complex 80W	2.1	18	15	82	75	1
Zinc ion–maneb complex 80W	4.2	2	2	85	65	1

[a] Percentage of active ingredient and formulation type (W = wettable powder, L = liquid, F = flowable, D = dust, and EC = emulsifiable concentrate).
[b] PS = poor stand.

following summer.

The fungicides tested during the 10-yr period (1969–1978) were: benomyl, 50% (Benlate) (E. I. du Pont de Nemours & Co.); captan, 50% (Orthocide) (Chevron Chemical Co.); carbendazim, 15% + maneb, 60% (DPX-14) (E. I. du Pont de Nemours & Co.); carboxin, 75%, 34% (Vitavax, UNI-1080) (Uniroyal, Inc.); carboxin, 37.5% + captan, 37.5% (Vitavax + captan) (Uniroyal, Inc.); carboxin, 37.5%, 17% + thiram, 37.5%, 17% (Vitavax + thiram, UNI-1090, UBI-1196, Vitavax 200) (Uniroyal, Inc.); CGA-64251, 21.5% = 1-[[2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-yl] methyl]-1*H*-1,2,4-triazole (Ciba-Geigy Corp.); chloranil, 95% (Spergon) (Uniroyal, Inc.); chlorine dioxide, 2% (DI-17) (Danner Industries); chloroneb, 65% (Demosan) (E. I. du Pont de Nemours & Co.); copper carbonate, 5% (TC-905) (Troy Chemical Corp.); dicloran, 75% (Botran) (The Upjohn Co.); fenapanil, 36%, 24.2% (Sisthane) (Rohm and Haas Co.); fenarimol, 12.5% (EL-222) (Eli Lilly & Co.); fuberidazole, 50% (BAY 33172) (Mobay Chemical Corp.); hexachlorobenzene, 18% + captan, 18% (Ortho WSP) (Chevron Chemical Co.); hexachlorobenzene, 5% + maneb, 25% (Granox) (ICI Americas, Inc.); hexachlorobenzene, 20% + captan, 20% + maneb, 15% (Res-Q) (Gordon Corp.); maneb, 50% (Agsco DB Yellow) (Agsco Chemicals, Inc.); maneb, 50% + lindane, 18.7% (Agsco DB Green) (Agsco Chemicals, Inc.); metalaxyl, 50% (CGA 48988) (Ciba-Geigy Corp.); methfuroxam, 75%, 6%, 4.2% (H-719, UBI-1160, UBI-1195) (Uniroyal, Inc.); methfuroxam, 5% + thiram, 25.8% (UBI-1194) (Uniroyal, Inc.); methfuroxam, 12.5% + zinc ion–maneb complex, 62.5% (UBI-1159) (Uniroyal, Inc.); metiram, 53% (Polyram) (FMC Corp.); nuarimol, 9.5% (EL-228) (Eli Lilly & Co.); octhilinone, 90% (RH-893) (Rohm and Haas Co.); oxycarboxin, 75% (Plantvax) (Uniroyal, Inc.); PCNB, 75%, 24% (Terraclor, Terra-Coat LT-2) (Olin Corp.); PCNB, 23.2%, 22.8% + ethazol, 5.8%, 11.4% (Terra-Coat L-205, Terra-Coat L-21) (Olin Corp.); phenylmercuric ammonium acetate, 3.5% (Mist-o-matic) (Gustafson Manufacturing Co.); pyracarbolid, 50% (HOE-2989) (American Hoechst Corp.); TCMTB, 60%, 30% (Busan 72) (Buckman Laboratories, Inc.); thiabendazole, 60%, 42%, 30% (Mertect 160, Mertect 140, Mertect LSP) (Merck & Co., Inc.); thiophanate-methyl, 70% (TD-1771) (Pennwalt Corp.); thiram, 65% (Thylate) (E. I. du Pont de Nemours & Co.); triadimefon, 25% (BAY MEB 6447, Bayleton) (Mobay Chemical Corp.); triadimenol, 25% (BAY KWG-0519) (Mobay Chemical Corp.); triazbutil, 80% (RH-124) (Rohm & Haas Co.); and zinc ion–maneb complex, 80% (Dithane M-45) (Rohm and Haas Co.). Hexachlorobenzene, 40% (Anticarie 40) (H. P. Rossiger & Co.) and cyano (methylmercuri) guanidine, 2.2% (Panogen 15) (Nor-Am Agricultural Products, Inc.) were used as standards for comparison in all tests.

RESULTS

When either seed or soil was inoculated, high levels of common bunt developed in plants grown from untreated seed at both locations in each year (Table 1). Thus, severe infection conditions were provided for the evaluation of the fungicide treatments.

Seed-treatment fungicides (other than the standard 40% hexachlorobenzene) that controlled both seedborne and soilborne common bunt at rates of 4.2 g/kg or 4.3 ml/kg (6.7 oz/cwt) or less were: 75% carboxin; 37.5% carboxin in combination with captan or thiram; 21.5% CGA-64251; 36% or 24.2% fenapanil; 18% hexachlorobenzene in combination with captan; 20% hexachlorobenzene in combination with captan and maneb; 75% or 6% methfuroxam; 5% methfuroxam in combination with thiram; 12.5% methfuroxam in combination with zinc ion–maneb complex; 9.5% nuarimol; 75% or 24% PCNB; 23.2% PCNB in combination with ethazol; 60%, 42%, or 30% thiabendazole; 25% triadimefon and 25% triadimenol (Table 1).

Nonmercurial fungicides that controlled seedborne but not soilborne bunt at rates of 4.2 g/kg or 4.3 ml/kg or less were: 50% benomyl; 34% carboxin; 17% carboxin in combination with thiram; 65% chloroneb; 50% fuberidazole; 5% hexachlorobenzene in combination with maneb; 50% maneb; 22.8% PCNB in combination with ethazol; 50% pyracarbolid; 60% or 30% TCMTB; and 80% zinc ion–maneb complex (Table 1). Phytotoxicity, expressed as delayed or reduced seedling emergence and reduced number of heads at maturity, was observed with CGA-64251, fenarimol, and nuarimol at the higher rates of treatment. However, these observations were not quantified.

DISCUSSION

These results indicate that several fungicides could effectively add to or replace the seed-treatment materials now in use for control of seedborne and soilborne common bunt. Indeed, CGA-64251, methfuroxam, and triadimenol appear to be effective at lower rates than hexachlorobenzene, long considered the epitome of bunt-controlling materials.

Isolated outbreaks of common bunt have occurred in the United States and other countries when seed treatment was interrupted or discontinued (5,22). The presence of *T. caries* and *T. foetida* teliospores in grain samples led Mathre and Johnston (18) to conclude that sufficient inoculum is present in Montana to lead to increased incidence of common bunt with sizable economic effect if seed treatment were discontinued. The continued use of effective seed-treatment materials assumes greater importance when it is considered that many wheat cultivars grown in the western United States are susceptible to one or more races of the common bunt organisms (10,13).

Another reason for continued use of seed treatments for wheat in the northwestern United States is to prevent the introduction of seedborne spores of new races of dwarf bunt into areas where they do not now occur. Although none of the seed treatments tested thus far, except thiabendazole, provides adequate protection against dwarf bunt infection (12), other fungicides may kill or inhibit the germination of dwarf bunt spores on seed (14).

Experience has shown that common bunt teliospores do not remain viable in soil for more than 2 yr (14,15). Thus, the high degree of common bunt control maintained over the past 20 yr has presumably reduced the level of soilborne inoculum to insignificance, and a consistently high level of control of seedborne bunt might preclude the future buildup of soilborne inoculum. However, the use of mercurial-based fungicides, which were highly effective against seedborne bunt, did not prevent or alleviate the soilborne bunt problem in the Pacific Northwest (14). Therefore, it may be premature to conclude that the use of fungicides effective only against seedborne bunt will prevent the reestablishment of soil infestation in the region, with possibly serious consequences.

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