Chemical Seed Treatments for Control of Barley Leaf Stripe in California

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ABSTRACT

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Barley leaf stripe, a seedborne disease caused by *Drechslera graminea*, has become a serious problem in the absence of an effective seed treatment. For this reason, field trials were conducted during three consecutive harvest years (1982–1984) to identify a suitable seed treatment for control of barley leaf stripe. Several fungicides tested provided a high level of disease control. Three of these, imazalil, CGA-64251, and iprodione, gave nearly complete control of barley stripe without phytotoxicity.

Barley leaf stripe is caused by the seedborne pathogen *Drechslera graminea* (Rab.) Shoem. (perfect state *Pyrenophora graminea* Ito & Kurib). Mycelium within the hull and pericarp infects the barley (*Hordeum vulgare* L.) seedling before it emerges from the soil (6). Symptoms of the disease include necrotic striping and splitting of the leaves; infected plants produce little or no harvestable grain (4,9). Because barley leaf stripe is a single-cycle disease and infested seed is the only source of inoculum, an effective seed treatment will provide complete control (10). Mercurial fungicides were used for this purpose until their use was banned by the federal government (3). In the absence of an effective control measure, the incidence of barley stripe has increased substantially (3). For this reason, effort has been directed toward identification of a fungicidal seed treatment for control of barley stripe. This paper reports on the efficacy and phytotoxicity of fungicidal seed treatments as determined from 3 yr of field testing in California.

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MATERIALS AND METHODS

The first field trial was planted in 1982 at the Davis campus of the University of California. Kombyne barley seed with a 40% *D. graminea* infestation was used. Infestation level was determined by plating seed as described by Teviotdale and Hall (10). The fungicides tested were GUS-215 (50%, 2,5-dimethyl *N*-cyclohexyl-*N*-methoxy-3-furancarboximide, Gustafson); nuarimol (97.9%, EL-228, Eli Lilly); RTU PCNB (24%, PCNB, Cargill); vinclozolin (50%, Ronilan, BASF Wyandotte); iprodione (50%, Rovral, Rhone-Poulenc); carboxin (34%, Vitavax, Uniroyal); imazalil (75%, Fungaflor, Janssen Pharmaceutica); CGA-64251 [13.5%, 1(2-(2,4-dichlorophenyl)-4-ethyl-1,3-dioxolan-2-ylmethyl)-1-*H*-1,2,4-triazole, Ciba-Geigy]; carboxin (10%) + thiram (10%) (RTU 1010, Cargill); triadimenol (8.05%, Baytan, Mobay); BAS 389 01 F [50%, (*N*-cyclohexyl-*N*-methoxy)-2,5-dimethyl-3-furancarboximide, BASF Wyandotte]; prochloraz (40%, BFC Chemical, Inc.); and 5781 F (18%, Rohm & Haas). Untreated seed and seed treated with volatile mercury (Ceresan L, du Pont de Nemours) were included as controls.

All chemical formulations tested were diluted to 6 ml with tap water and applied to 114 g of seed. Chemicals were applied by slowly pouring the diluted formulation over the seeds, which were mechanically tumbled to ensure uniform coverage. The seeds were planted on 28 December 1981 in single-row, 3-m plots (100 seeds per row) in a randomized complete block design with four replicates. Just before heading, plants were examined for symptoms of barley leaf stripe. Plants with leaves showing the distinctive pattern of necrotic striping were rated diseased; plants free of these symptoms were rated healthy. Every plant in each plot was included in the disease ratings and in stand counts that were conducted at the same time.

The 1983 trial was planted at Davis in a different location from the 1982 plantings. Kombyne barley seed with a 70% *D. graminea* infestation was used. Except for RTU PCNB, vinclozolin, and carboxin, all fungicides described for the 1982 trial were tested again in 1983. Also included in the 1983 trials were 30% PH 51-04 (Duphar); triadimenol (4%) + carboxin (4%) (GUS-301, Gustafson); triadimenol (5%) + thiram (15.3%) (Cargill); carboxin (17%) + maneb (17%) (Gustafson); carboxin (17%) + thiram (17%) (Vitavax 200, Uniroyal); and triadimenol (20%) + imazalil (3.3%) (Wilbur-Ellis). Ceresan-treated and untreated seed were included as controls.

Fungicides were applied to seed as described for the 1982 trial. The seeds were planted on 4 January 1983 in single-row, 6-m plots (200 seeds per row) in a randomized complete block design with four replicates. Every plant was included in the disease ratings and stand counts that were conducted just before heading.

Seven fungicides included in the 1983 field trial were also used to treat seed for a greenhouse study to evaluate possible phytotoxicity of the treatments. The fungicides included in this test were imazalil, iprodione, CGA-64251, RTU 1010, triadimenol, 5781 F, and prochloraz. Untreated seeds were included as a control. Seeds were treated as described previously. For each treatment, a sample of 100 seeds was sown in a flat of pasteurized U.C. mix (5); each treatment was replicated three times. Emergence was evaluated 14 days after seeding, when all viable seeds had produced emergent seedlings. Fifteen days after seeding, all seedlings were harvested and the soil washed from their roots. The seedlings were dried at 60 C for 48 hr and weighed.

The 1984 field trials were planted in five locations representative of the barley-growing areas in California. One field was located in each of the following five counties: Butte, Sutter, and Yolo (Sacramento Valley) and Fresno and Kings (San Joaquin Valley). The seed used in these trials included the variety Prato, with about 15% *D. graminea* infestation, and Kombyne, the same seed lot used in the 1983 plantings. The fungicides tested in these trials were imazalil, 5781 F, CGA-64251, iprodione, prochloraz, Vitavax 200, PCNB (Terra-Coat Lt-2, Olin), and Ceresan. All treatments were applied to the Prato seed lot; untreated Prato seed was included as a control. Kombyne seed was either treated with imazalil or untreated.

Fungicides were applied to the seed as described for the 1982 trial, except 2.3-kg samples of seed were treated and chemicals to be applied were diluted to 10 ml with tap water. Seeds were planted in six-row plots (1.2 × 6.5 m) in a randomized complete block design with four replicates. At maturity, each plot was harvested for yield determinations. Disease levels were estimated by visual inspection of each plot just before heading.

RESULTS

Trials conducted in 1982 included a number of treatments at one or more rates that gave little or no control of barley leaf stripe. Data for these treatments are not included in this report. All treatments shown in Table 1 gave a significant level of disease control. Only GUS-215 failed to provide disease control statistically comparable to that of Ceresan. Five treatments caused a significant reduction in stand count: BAS 389 01 F, prochloraz, iprodione, and 5781 F (all at 1.25 g a.i./kg of seed) and CGA-64251 (at 0.132 ml a.i./kg of seed). The high level of disease in the untreated check indicates that conditions were suitable for infection to occur in the absence of an effective treatment.

Fungicides that were as effective as Ceresan in 1982 were tested again in 1983, with the exception of carboxin and

Table 1. Effects of chemical seed treatments on incidence of barley stripe and stand establishment in Kombyne barley seed with a 40% *Drechslera graminea* infestation (1982)

Treatment	Rate (a.i./kg of seed)	Percent disease[y]	Av. no. of plants at heading[z]
Untreated check	···	27.8 a	69.0 a
GUS-215 (50%)	0.240 ml	8.8 b	63.3 ab
EL-228 (97.9%)	0.075 g	4.1 c	52.8 abcde
RTU PCNB (24%)	0.470 ml	3.7 c	63.0 ab
Vinclozolin (50%)	1.250 g	2.1 c	54.3 abcde
Iprodione (50%)	1.880 g	2.0 c	51.8 abcde
Carboxin (34%)	2.500 g	1.9 c	61.8 abc
Vinclozolin (50%)	2.500 g	1.7 c	48.0 abcde
Carboxin (34%)	1.250 g	1.7 c	51.5 abcde
Imazalil (75%)	0.198 g	1.3 c	52.5 abcde
Ceresan (3.5%)	0.088 g	1.3 c	64.3 a
Ceresan (3.5%)	0.044 g	0.9 c	54.0 abcde
CGA-64251 (13.5%)	0.132 ml	0.7 c	41.0 bcde
Imazalil (75%)	0.066 g	0.5 c	58.3 abcd
RTU 1010 (10%)	0.280 ml	0.4 c	67.0 a
Triadimenol (8.05%)	0.180 ml	0.4 c	49.3 abcde
Iprodione (50%)	0.630 g	0.4 c	62.8 abc
BAS 389 01 F (50%)	1.250 g	0.4 c	34.3 e
5781 F (18%)	0.630 g	0.0 c	47.8 abcde
BAS 389 01 F (50%)	0.630 g	0.0 c	56.8 abcd
Prochloraz (40%)	1.250 g	0.0 c	37.0 de
5781 F (18%)	1.250 g	0.0 c	33.3 e
Iprodione (50%)	1.250 g	0.0 c	40.5 cde
Imazalil (75%)	0.132 g	0.0 c	47.0 abcde

[y] Percentage of diseased plants at heading, average of four replicates. Means followed by a common letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

[z] Each value is the mean of four replicates; 100 seeds were planted for each replicated treatment. Means followed by a common letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

Table 2. Effects of chemical seed treatments on incidence of barley stripe and stand establishment in Kombyne barley seed with a 70% *Drechslera graminea* infestation (1983)

Treatment	Rate (a.i./kg of seed)	Percent disease[y]	Av. no. of plants at heading[z]
Untreated check	···	46.9 a	127
PH 51-04 (30%)	0.300 g	8.1 bc	131
EL-228 (97.9%)	0.075 g	6.5 bc	137
GUS-215 (50%)	0.488 ml	5.5 bc	125
BAS 389 01 F (50%)	0.630 g	4.2 bc	108
GUS-301 (4%)	0.080 g	3.6 bc	115
Triadimenol (7.95%)	0.160 ml	3.3 bc	133
Triadimenol (5%) + thiram (15.3%)	0.195/0.600 ml	3.2 bc	90
Ceresan (3.5%)	0.046 ml	2.8 bc	126
CGA-64251 (13.5%)	0.020 g	2.0 bc	132
Carboxin (17%) + maneb (17%)	0.880 ml	1.8 c	139
Carboxin (17%) + thiram (17%)	0.880 ml	1.1 c	103
RTU 1010 (10%)	0.280 ml	0.9 c	141
Triadimenol (5%) + thiram (15.3%)	0.145/0.440 ml	0.4 c	130
Imazalil (75%)	0.100 g	0.3 c	128
Triadimenol (20%) + imazalil (3.3%)	0.300/0.050 g	0.3 c	109
5781 F (18%)	0.630 g	0.0 c	104
Imazalil (75%)	0.075 g	0.0 c	101
CGA-64251 (13.5%)	0.040 g	0.0 c	119
Prochloraz (40%)	0.630 g	0.0 c	75
Iprodione (50%)	1.250 g	0.0 c	118

[y] Percentage of diseased plants at heading, average of four replicates. Means followed by a common letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.

[z] Each value is the mean of four replicates; 200 seeds were planted for each replicated treatment. There was no significant difference among chemical treatments at $P = 0.05$ according to Duncan's multiple range test.

vinclozolin (Table 2). Carboxin, although not tested by itself in 1983, was included in several combination treatments. GUS-215, although inferior to Ceresan in controlling barley stripe, was tested again in 1983 because other work (2) indicated it should be effective at rates higher than those used in 1982. All fungicides tested in 1983 gave a significant level of disease control (Table 2). Several of these treatments failed to control the disease as effectively as Ceresan, but these differences were not statistically significant. As in 1982, a high level of disease occurred in the untreated check, indicating that field conditions were suitable for infection of the barley seedlings. Several of the treatments caused a reduction in stand count relative to the untreated control, especially prochloraz and triadimenol combined with thiram at 0.195/0.600 ml a.i./kg seed. However, these differences were not statistically significant.

The results of the greenhouse experiments to determine emergence, dry weight, and dry weight per plant are shown in Table 3. Three treatments, 5781 F at 0.950 g a.i./kg of seed and prochloraz at both rates produced a statistically significant decrease in the total dry weight of the emerged seedlings. These three treatments, and RTU 1010 at 0.42 ml a.i./kg of seed, caused a statistically significant decrease in emergence. There was no significant difference among treatments in the dry weight per seedling (Table 3); however the prochloraz-treated seed produced seedlings that were deformed. They were twisted, and shorter and more succulent than seedlings in the other treatments.

Table 3. Effects of chemical seed treatments on emergence, total dry weight, and dry weight per plant of Kombyne barley seed with a 70% *Drechslera graminea* infestation

Treatment	Rate (a.i./kg of seed)	Emergence[x]	Dry wt[y] (g)	Dry wt per plant[z] (g)
Imazalil (75%)	0.100 g	97.3	4.33 a	0.045
Iprodione (50%)	1.900 g	94.7	4.20 a	0.044
CGA-64251 (13.5%)	0.060 g	94.7	4.09 a	0.043
RTU 1010 (10%)	0.280 ml	94.3	4.09 a	0.043
Imazalil (75%)	0.150 g	96.7	4.06 a	0.042
Untreated check	···	97.7	4.01 a	0.041
CGA-64251 (13.5%)	0.040 g	95.3	3.93 ab	0.041
Triadimenol (7.95%)	0.240 ml	95.0	3.90 ab	0.041
5781 F (18%)	0.630 g	95.7	3.87 ab	0.040
Triadimenol (7.95%)	0.160 ml	95.0	3.87 ab	0.041
Iprodione (50%)	1.250 g	95.0	3.84 ab	0.040
RTU 1010 (10%)	0.420 ml	93.7 d	3.79 ab	0.041
5781 F (18%)	0.950 g	92.7 d	3.46 b	0.037
Prochloraz (40%)	1.250 g	61.7 d	2.45 c	0.040
Prochloraz (40%)	1.900 g	49.3 d	2.06 c	0.042

[x] The number of seedlings emerged 2 wk after sowing 100 seeds per flat in pasteurized U.C. mix. Each value is the mean of three replicates. Means followed by the letter d are significantly lower than the untreated check at $P = 0.05$ according to Duncan's multiple range test.
[y] The total dry weight of the seedlings 15 days after sowing. Each value is the mean of three replicates. Means followed by a common letter are not significantly different at $P = 0.05$ according to Duncan's multiple range test.
[z] Mean dry weight per plant. Each value is the mean of three replicates. There was no significant difference among the means at $P = 0.05$ according to Duncan's multiple range test.

Table 4. Effects of chemical seed treatments on yield of Prato and Kombyne barley (1984)

Variety	Treatment	Rate (a.i./kg of seed)	Yield (kg/ha) by counties[a]				
			Butte	Sutter	Yolo	Fresno	Kings
Prato[b]	Imazalil (75%)	0.100 g	6,610	6,010	6,280	6,090	5,400
	5781 F (18%)	0.630 g	6,780	5,250	6,100	6,570	5,290
	Ceresan (3.5%)	0.046 ml	7,010	5,430	6,840	6,260	5,530
	CGA-64251 (13.5%)	0.040 g	6,620	6,080	5,980	5,840	4,890
	Iprodione (50%)	1.250 g	6,660	6,090	5,880	5,980	5,620
	Prochloraz (40%)	0.300 g	6,610	5,870	6,430	6,280	4,700
	Carboxin (17%) + thiram (17%)	0.880 ml	6,830	6,400	6,360	6,310	5,220
	Terra-Coat Lt-2 (24%)	1.250 g	6,660	5,890	6,450	6,370	5,630
	Untreated check	···	6,240	6,110	6,430	6,060	5,390
Kombyne[c]	Imazalil (75%)	0.100 g	5,690	4,980	4,920	5,910	5,610
	Untreated check	···	3,690	3,850	2,990	4,680	3,310

[a] Yield data represent the mean of four replicates. There was no significant difference among the treated and untreated Prato at $P = 0.05$. Yield of imazalil-treated Kombyne was significantly higher than untreated Kombyne at $P = 0.05$.
[b] About 15% of the Prato seed was infested with *Drechslera graminea*. Untreated Prato had 5, 1, 5, 8, and 10% barley stripe at Butte, Sutter, Yolo, Fresno, and Kings counties, respectively. All other treatments had less than 1% barley stripe (Butte) or were free of barley stripe (other locations).
[c] About 70% of the Kombyne seed was infested with *D. graminea*. Untreated Kombyne had 50% barley stripe at all locations; imazalil-treated Kombyne was free of barley stripe.

For the variety Prato, planted at five locations, none of the fungicidal treatments significantly increased yield compared with the untreated control (Table 4). The levels of barley stripe on untreated Prato ranged from 1 to 10%; fungicide treatments reduced disease levels to less than 1%. Imazalil-treated Kombyne was free of barley stripe at all five locations (Table 4) and yielded substantially more than untreated Kombyne, which had 50% stripe at all locations.

DISCUSSION

All fungicidal seed treatments for which data are presented caused a significant decrease in the level of barley stripe relative to the untreated controls. The most consistently effective of these fungicides were imazalil, CGA-64251, prochloraz, and iprodione. Imazalil, CGA-64251, and prochloraz are systemic, sterol synthesis inhibitors (8); iprodione is not. Iprodione is a contact fungicide but has shown systemic activity in grasses (1,7).

Materials containing carboxin, triadimenol, or both, such as RTU 1010 (10% carboxin + 10% thiram) and triadimenol (5%) + thiram (15.3%), gave high levels of disease control. However, the Vitavax 200 treatment (at about 2.5 times the recommended rate) provided five times as much of the same active ingredients as RTU 1010 without enhancing disease control.

Results from the 1984 trials show that no significant difference in yield resulted from fungicidal treatment of infested Prato seed. It is possible that a beneficial effect of disease control was offset by a phytotoxic effect of the seed treatments. This seems unlikely because, of the treatments tested in 1984, only prochloraz was phytotoxic in earlier trials, and it was applied at half the lowest rate previously tested. The lack of a yield increase in the untreated Prato seed may be explained in part by the observation that diseased plants had late-forming tillers free of stripe that produced havestable grain. Thus infected plants do not necessarily represent a complete loss of yield. Also, there probably was some yield compensation by neighboring plants that were not infected. For these reasons, controlling barley stripe in a seed lot with a low level of infested seed may not result in a yield increase. However, if a low level of disease is allowed to develop in a stand of barley, the seed produced by that stand may have a much higher level of infestation (10). When a large percentage of seed is infested with *D. graminea*, such as the Kombyne seed used in 1984, an effective seed treatment can have a significant impact on yield.

The most effective fungicides tested for control of barley stripe, without phytotoxicity, were imazilil, CGA-64251, and iprodione. Prochloraz was also effective and can probably be used without phytotoxicity at rates below 0.3 g a.i./kg of seed (2). Iprodione is registered for use as a cereal seed treatment in Europe. Imazalil is now registered for use as a cereal seed treatment both with the Environmental Protection Agency and the state of California.

LITERATURE CITED

1. Danneberger, T. K., and Vargas, J. M., Jr. 1982. Systemic activity of iprodione in *Poa annua* and postinfection activity for *Drechslera sorokiniana* leaf spot management. Plant Dis. 66:914-915.
2. Johnston, R. H., Metz, S. G, and Riesselman, J. H. 1982. Seed treatment for control of Pyrenophora leaf stripe of barley. Plant Dis. 66:1122-1124.
3. Mathre, D. E., Metz, S. G., and Johnston, R. H. 1982. Small grain cereal seed treatment in the postmercury era. Plant Dis. 66:526-531.
4. Mathur, R. S., Mathur, S. C., and Bajpai, G. K. 1964. An attempt to estimate loss caused by the stripe disease of barley. Plant Dis. Rep. 48:708-710.
5. Matkin, O. A., and Chandler, P. A. 1957. The U.C.-type soil mixes. Pages 68-75 in: The U.C. System for Producing Healthy Container-Grown Plants. K. F. Baker, ed. University of California Agricultural Extension Service. 332 pp.
6. Platenkamp, R. 1976. Investigation on the infection pathway of *Drechslera graminea* in germinating barley. K. Vet. Landbohoejsk. Arsskr. 1976:49-64.
7. Sanders, P. L., Burpee, L. L., Cole, H., and Duich, J. M. 1978. Control of fungal pathogens of turfgrass with the experimental iprodione fungicide, RP26019. Plant Dis. Rep. 62:549-553.
8. Siegel, M. R. 1981. Sterol-inhibiting fungicides: Effects on sterol biosynthesis and sites of action. Plant Dis. 65:986-989.
9. Tekauz, A., and Chiko, A. W. 1980. Leaf stripe of barley caused by *Pyrenophora graminea*: Occurrence in Canada and comparisons with barley stripe mosaic. Can. J. Plant Pathol. 2:152-158.
10. Teviotdale, B. L., and Hall, D. H. 1976. Factors affecting inoculum development and seed transmission of *Helminthosporium gramineum*. Phytopathology 66:295-301.