Control of Strawbreaker Foot Rot of Winter Wheat by Fungicides in Washington

G. W. BRUEHL, Plant Pathologist, and R. MACHTMES, Technical Aide, Department of Plant Pathology, Washington State University, Pullman, and R. J. COOK, Research Plant Pathologist, USDA-ARS, Pullman 99164-6430.

ABSTRACT

Bruehl, G. W., Machtmes, R., and Cook, R. J. 1982. Control of strawbreaker foot rot of winter wheat by fungicides in Washington. Plant Disease 66:1056-1058.

Benomyl as a foliar spray protected winter wheat against strawbreaker foot rot over a wider range of application dates than did thiabendazole. Benomyl was also superior to thiophanate methyl in the single test conducted with the latter material. Fungicide applications in January–March were most effective in suppressing foot rot of the wheat cultivar Stephens, whereas March–April applications were most effective for the cultivar Daws. Economic rates of fungicides were ineffective when applied in November or May regardless of cultivar, and oil did not enhance the efficacy of the fungicides.

Experiments to control strawbreaker foot rot, incited by *Pseudocercosporella herpotrichoides* (Fron) Deighton, with fungicides in Washington began in the fall of 1967 (1). Work since that time, mostly with benomyl, indicated that rates from 0.14 to 1.12 kg/ha (1/8–1 lb a.i./acre) produce measurable increments of control in eastern Washington (1,2). The recommended 0.56 kg/ha (1/2 lb/acre) gives only partial control but prevents severe losses.

Scientific Paper 5863, Project 0110, College of Agriculture Research Center, Washington State University.

This work was supported by the Washington State Wheat Commission, Merck and Co., E. I. du Pont de Nemours & Co., and the Pennwalt Corp.

Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply approval of it to the exclusion of other products that may also be suitable.

Accepted for publication 22 April 1982.

Thiabendazole (TBZ), 42 g a.i./100 ml of carrier, was compared with benomyl on several occasions (*unpublished*). At three locations in 1971–1972, benomyl increased yields by an average of 875 kg/ha (13 bu/acre) and TBZ by 740 kg/ha (11 bu/acre). At two locations in 1974–1975, benomyl increased yields by an average of 1,750 kg/ha (26 bu/acre) and TBZ by 808 kg/ha (12 bu/acre). At one location in 1975–1976, benomyl increased yields by 1,211 kg/ha (18 bu/acre) and TBZ by 471 kg/ha (7 bu/acre). These unreported observations led us to use benomyl and not TBZ in subsequent experiments (1,3,4).

Farmers in Washington were slow to adopt foliar sprays to control foot rot until 1979. About 80,000 ha (200,000 acres) in 1980 and 100,000 ha (250,000 acres) in 1981 were sprayed in Washington. Fungicide applications in the state now cost more than $3 million per year. These developments prompted us to evaluate further the efficacy of alternative fungicides for the control of foot rot.

MATERIALS AND METHODS

Selection of sites. With one exception, all experiments were conducted on farm fields with natural inoculum. The exception was the 1972–1973 experiment on the Washington State University Agronomy Farm, where oat kernels infested with *P. herpotrichoides* were applied in mid-October, about 1 mo after sowing (2). Of the six naturally infested fields, four were in Whitman and Spokane counties in eastern Washington, where annual precipitation exceeds 80 cm and strawbreaker foot rot is traditionally most severe. Two sites were in the Horse Heaven Hills of Benton County in south central Washington, where annual precipitation is less than 25 cm and strawbreaker foot rot is severe only in exceptional seasons. All fields were seeded in early fall (during September), which favors the disease. All sites were on level or gently sloping land with uniform stands.

Application of fungicides. Benomyl (Benlate 50% WP) was applied at rates up to 2.2 kg a.i./ha (2 lb/acre). TBZ (Mertect 340F) was applied as a flowable formulation at rates of 1.2–7.4 L/ha (16–96 fl oz/acre). All fungicides were applied with 75 L of water per hectare (20 gal/acre) using either a backpack sprayer or a spray boom 2.4 m long with the nozzles 30 cm apart.

Assessment of disease. Visual disease assessments and yields were used to determine the effect of the fungicides. In one experiment (1972–1973), white heads were used to estimate disease. In all other experiments, plants were dug and disease was assessed on the basis of number and severity of lesions at the base of the stems using a system similar to that of Huber and Mulanax (7). Each datum was based on a minimum of 200 stems. A four-point disease index was used, with 0 = all stems healthy, 1 = light lesions, 2 and 3 = increasingly severe lesions, and 4 = all stems severely lesioned or dead.

Yields were obtained from the centers of the plots. The wheat was cut and bound by hand and threshed with a Vogel stationary bundle thresher.

RESULTS

1972–1973. Nugaines (CI 13968) winter wheat was seeded on 15 September 1972 on the Agronomy Farm, Pullman, WA. Oat kernels infested with *P. herpotrichoides* were broadcast over the soil surface 1 mo after emergence. Benomyl was applied on dates ranging from 16 November 1972 to 14 May 1973. Efficacy was judged by estimation of the incidence of white heads on 11 July 1973. Benomyl applied 16 November 1972 and 14 May 1973 was ineffective (Fig. 1). Benomyl sprays applied from 2 February to 30 April were equally effective (LSD [0.05] = 14.8%).

1975–1976. Wanser (CI 13844) winter wheat was sprayed at two locations in the Horse Heaven Hills, one about 30 km west of Kennewick (Semmelink Farm), WA, and the other about 20 km south of Kennewick (Owens Farm). The Semmelink field was sown 7 September and the Owens field 30 August 1975. Benomyl and TBZ were applied at 1.12 kg and 2.8 L of formulation per hectare, respectively (equivalent of 1 lb a.i./acre each). One set of plots was sprayed 10 December 1975, and another set was sprayed 11 February 1976. There were three replicates in a randomized block design. The percentage of stems with lesions was determined from 100 culms per plot selected randomly in June.

Neither fungicide was effective when applied in December, in spite of the wheat being well tillered at the time of spraying. Both fungicides applied in February resulted in significantly ($P = 0.05$) fewer stems with lesions, with benomyl giving the fewest infected stems at both locations. Yields were low at both locations, and only benomyl applied in February at the Owens (earliest sown) location gave a significant yield increase. Actual average yields (kg/ha) for the February applications at the Semmelink location were 2,238, 2,542, and 2,450 for the check, TBZ, and benomyl, respectively, and at the Owens location were 2,733, 3,087, and 3,384 for the check, TBZ, and benomyl, respectively. Percentages of stems with lesions were 43, 15, and 10 for the check, TBZ, and benomyl applied at the Semmelink location; and 72, 32, and 14 for these same respective treatments at the Owens location.

1976–1977. McDermid (CI 14565) winter wheat was seeded 8 September 1976 near Pullman on fertile, summer-fallowed land following winter wheat. On 8 April 1977, benomyl was applied at 1.12 kg a.i./ha (1 lb/acre) and TBZ at 1.2–7.4 L/ha (16–94 fl oz of product per acre). The five treatments plus a check were in a randomized block design with six replicates. Percentage of stems with lesions and yields were recorded at maturity. TBZ did not equal benomyl, either in reducing the number of diseased stems or in increasing yield (Table 1). Phytotoxicity was not observed with TBZ applied at a very high rate.

1979–1980. Daws (CI 17419) winter wheat was sprayed in a field 13 km northwest and Stephens (CI 17569) in a field 3 km northeast of Pullman. The wheat in both fields was seeded 15 September 1979 on summer fallow. The preceding winter wheat crops in these fields had severe foot rot. Benomyl and TBZ were applied at 0.56 kg and 1.75 L a.i./ha (1/2 lb and 24 fl oz/acre), respectively, on dates ranging from 11 November 1979 to 14 May 1980.

Yields were not taken in either the Daws or Stephens fields because Cephalosporium stripe (caused by *Cephalosporium gramineum* Nis. & Ikata) was severe and spotty in both fields. Efficacy was limited to assessment of the severity and number of stem lesions (7). Four samples per control and per treatment, each consisting of approximately 200 stems, were used per datum. The spray treatments were in strips with controls on each side. The control data were averages of the strips on both sides of each treatment (ie, November control, November spray, November control, etc.).

Foot rot was very severe in the Daws field. The winter was mild, and volcanic ash from the Mount Saint Helens eruption covered the soil at this location 1 cm deep on 18 May (after the last spray). The effect of the ash on the severity of the disease is unknown.

Benomyl was the most effective in the 19 March and 21 April applications on Daws (Fig. 2) and from 16 January to 19 March on Stephens (Fig. 2). TBZ was most effective on Daws on 21 April and on Stephens from 15 January to 21 February 1980. Neither fungicide was effective on either cultivar when applied on 7 November or 14 May 1980. Daws is more susceptible to foot rot than Stephens.

1980–1981. Nugaines was seeded on a farm in Spokane County on 23 September 1980 immediately following winter wheat that had severe foot rot, with no intervening fallow or rotational crop. Individual plots were 2 × 7 m with six replicates. Samples for the determination of stem lesions were removed 13 July. Yields were determined at maturity by harvesting areas measuring 0.62 × 5 m. Volck Supreme Dormant oil (Ortho 480A) was applied at the rate of 1.2 L/ha with and without the fungicides. Stem lesion readings (Table 2) were more precise than yields in revealing the efficacy of these fungicides. Benomyl was superior to both TBZ and thiophanate methyl (Topsin M). The maximum yield response to fungicide treatment in this trial (1,010 kg/ha [15 bu/acre]) was small. The lack of adequate fertilization early in the development of the host may have reduced the response. Because the oil applied with the fungicide had no measurable effect, the data with and without oil were combined.

DISCUSSION

Based on both assessment of disease severity and yields, benomyl was superior to TBZ for the control of strawbreaker foot rot even though the active breakdown products of these materials are the same (8). We have only one experiment with thiophanate methyl (Table 2), but the

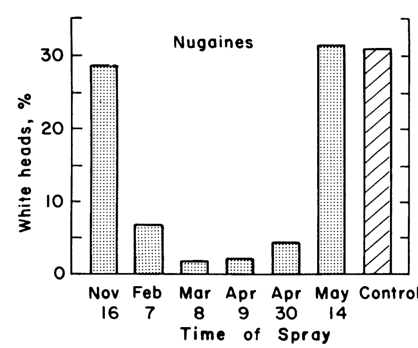

Fig. 1. Percentage of white heads from strawbreaker foot rot in Nugaines winter wheat, 1972–1973, indicates a wide range of effective dates (7 February–30 April) for the application of benomyl. LSD (0.05) = 14.8%.

Table 1. Effect of benomyl and thiabendazole (TBZ) on strawbreaker foot rot in McDermid winter wheat at Pullman, WA, 1976–1977

Treatment[x]	Infected stems[y] (%)	Yields[z] kg/ha	Yields[z] bu/acre
Control	76 a	3,392 e	50.4
Benomyl 1.12 kg/ha (1.0 lb/acre)	18 c	5,284 a	78.5
TBZ			
1.2 L/ha (16 fl oz/acre)	72 a	3,588 de	53.3
2.4 L/ha (32 fl oz/acre)	72 a	4,119 cd	61.2
4.9 L/ha (64 fl oz/acre)	51 ab	4,483 bc	66.6
7.4 L/ha (94 fl oz/acre)	35 abc	4,873 ab	72.4

[x] Applied 8 April 1977 using about 76 L of water per hectare (20 gal/acre). The Mertect 340F (TBZ) contained 42% a.i.

[y] Each value is based on the average for six replicates, at least 100 stems examined from each replicate.

[z] Each value is based on six replicates, two 4.8-m lengths of row harvested per replicate.

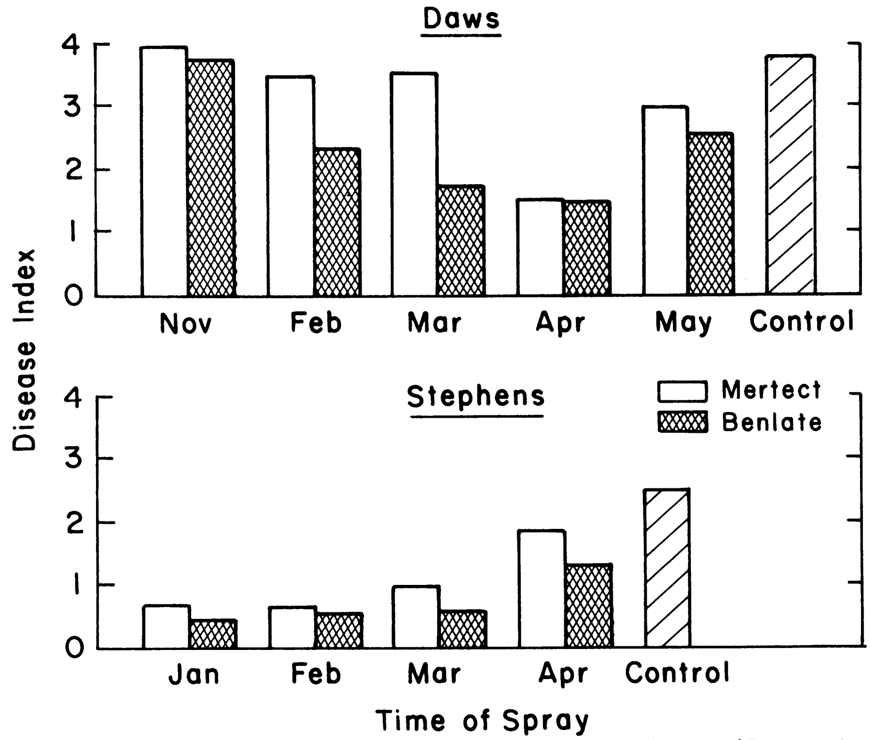

Fig. 2. Disease index (0 = healthy, 4 = dead or severe) of strawbreaker foot rot of Daws **(top)** and Stephens **(bottom)** cultivars of winter wheat near Pullman, WA, 1979–1980. Benomyl was applied at 0.56 kg/ha (1/2 lb/acre) and thiabendazole at 1.75 L/ha (24 fl oz/acre). LSD (0.05) for Daws is 0.61 and for Stephens, 0.20.

Table 2. Strawbreaker foot rot ratings (disease indexes) on stems and yields of naturally diseased Nugaines winter wheat in Spokane County, WA, July 1981

Treatment	Rate	Disease index[z]	Yield	
			kg/ha	bu/acre
Benomyl	0.28 kg a.i./ha	1.07	5,203	77.3
	0.56 kg a.i./ha	0.47	5,351	79.5
Thiabendazole	1.17 L a.i./ha	1.92	5,095	75.7
	1.75 L a.i./ha	1.78	5,008	74.4
Thiophanate methyl	0.42 kg a.i./ha	1.95	4,718	70.1
	0.84 kg a.i./ha	1.63	4,920	73.1
Control		2.40	4,335	73.1
LSD (0.05)		0.46	370	5.5

[z]0 = healthy, 4 = severe or dead.

conclusion that benomyl is superior to it seems justified.

Data in Figures 1 and 2 indicate that benomyl is effective over a wide range of spray dates. Flexibility in time of application is essential in Washington. Rainfall declines about 1 cm per 6.7 km from Pullman westward for a distance of about 140 km. Normal seeding dates are earlier in the drier areas, and plants at a given date during the early part of the growing season are larger in proportion to the decline in rainfall.

Fehrmann and Schrödter (6) in southern Germany and Defosse (5) in France reported that benomyl was most effective when applied after the period of greatest infection. Applications on 14 May were effective in Germany, and Huber and Mulanax (7) reported control in Idaho from sprays in May. Mid-May sprays are too late in eastern Washington.

Risk (9) in New Zealand associated spray dates with stage of host development. He found that sprays were satisfactory in the five- to six-leaf stage but more effective during stem elongation. Foot rot in Washington is severe mainly on early-seeded wheat. The crop enters winter with five to 10 tillers per plant, far beyond the five- to six-leaf stage. By 26 March in our 1980 trial, Stephens had 12 tillers per plant and it was beginning to joint, but the period of optimum response to fungicide in this cultivar was already past. The different response by Daws and Stephens (Fig. 2) to date of fungicide application indicates that proper timing may vary somewhat with the cultivar.

In an area of changing cultivars and variable environmental conditions, the ability of a fungicide to be effective from a single application over a wide range of dates is important. Benomyl appears to have this characteristic. The advantages of benomyl over TBZ and thiophanate methyl are greater than the data in the tables indicate. In comparing these fungicides, we ignored the fact that 24 fl oz of Mertect 340F (TBZ) contains more active ingredient than 1 lb of Benlate. Further, Benlate and Topsin M were applied at 1 lb of product per acre, even though Benlate contains 50% a.i. and Topsin 75% a.i.

LITERATURE CITED

1. Bruehl, G. W., and Cunfer, B. 1972. Control of Cercosporella foot rot of wheat by benomyl. Plant Dis. Rep. 56:20-23.
2. Bruehl, G. W., and Nelson, W. L. 1964. Techniques for mass inoculations with *Cercosporella herpotrichoides*. Plant Dis. Rep. 48:863-865.
3. Bruehl, G. W., Peterson, C. J., Jr., and Machtmes, R. 1974. Influence of seeding date, resistance, and benomyl on Cercosporella foot rot of winter wheat. Plant Dis. Rep. 58:554-558.
4. Cook, R. J., and Waldher, J. T. 1977. Influence of stubble mulch residue management on Cercosporella foot rot and yields of winter wheat. Plant Dis. Rep. 61:96-100.
5. Defosse, L. 1970. Essais de lutte chimique contre le piétin-versé (*Cercosporella herpotrichoides* Fron) avec un fongicide systémique. Parasitica 26:4-14.
6. Fehrmann, H., and Schrödter, H. 1972. Ökologische Untersuchungen zur Epidemiologie von *Cercosporella herpotrichoides*. IV. Erarbeitung eines praxisnahen Verfahrens zur Bekämpfung der Halmbruchkrankheit des Weizens mit systemischen Fungiziden. Phytopathol. Z. 74:164-174.
7. Huber, D. M., and Mulanax, M. W. 1972. Benomyl rates and application time for wheat foot rot control. Plant Dis. Rep. 56:342-344.
8. Richardson, L. T. 1973. Adaptive tolerance of *Fusarium solani* to benzimidazole derivatives in vitro. Can. J. Bot. 51:1725-1732.
9. Risk, W. H. 1974. Use of systemic fungicides for controlling eyespot lodging in wheat in Southland. N.Z. Wheat Rev. No. 12, 1971–1973. pp. 27-29.