Effect of Fungicides Applied Singly and in Combination on Seed Yield and Three Leaf Spot Diseases in Orchardgrass

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ABSTRACT

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Leaf diseases caused by *Mastigosporium rubicosum* (cause of eyespot), *Rhynchosporium orthosporum* (cause of scald), and *Cercosporidium graminis* (cause of leaf streak) were identified on orchardgrass (*Dactylis glomerata*) grown for seed. Fungicides (captafol, chlorothalonil, and propiconazole) were applied up to three times per year to plants in different stages of growth for 5 yr (1984–1988). Leaf area damaged by diseases (primarily scald) ranged from moderate to severe depending on the yearly variation in precipitation. In wet years, seed yields were significantly larger ($P = 0.05$) in plots treated with chlorothalonil than nontreated controls. Scores for leaf area damaged by disease in plots treated with chlorothalonil (when significantly different from controls) were inversely related to seed yield.

Additional keywords: forage, *Scolicotrichum graminis*, seed production

Leaf spot fungi in Western gramineae were documented by Sprague in a series of publications that culminated in 1962 (17). His book (16), lists 16 species of fungi imperfecti occurring in orchardgrass (*Dactylis glomerata* L.) in the Northwest U.S. Species in 17 genera of fungi infect foliage of orchardgrass (4).

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In cool-season grasses grown for turf, diseases caused by several of these fungi are generally more severe in cool, wet weather (15).

Although considerable literature has been published on fungal diseases of grasses for hay or pasture, little has been published on specific diseases of grasses grown for seed (11). Methods for managing leaf diseases in seed-production fields of orchardgrass are often limited because cultivars used as forage or pasture are usually developed for specific geographic locations outside of the seed-producing areas. As a result, cultivars usually are not genetically altered to incorporate resistance to pathogens occurring in seed-producing areas. Also, short crop rotation schedules are seldom used because a field may remain in seed production for five or more years.

Fungicides are an effective way to control leaf diseases, especially when more than one fungal pathogen occurs in the same plant. Their use has been studied extensively since the early 1940s for control of rust diseases in other cool-season grasses grown for seed (6,7). Recently, propiconazole was evaluated for control of *Mastigosporium rubricosum* (Dearn. & Barth.) Nannf. in orchardgrass (13); *Erysiphe graminis* DC., *Puccinia coronata* Corda, and *Drechslera* spp. in *Lolium perenne* L. (9,18); and *Claviceps purpurea* (Fr.:Fr.) Tul. in *Poa pratensis* L. (1).

This study investigated the appearance and severity of leaf diseases in orchardgrass, evaluated seed yield and leaf disease development in field plots treated with captafol, chlorothalonil, and propiconazole, and compared yearly variations in precipitation as it related to disease development and disease control. The time of fungicide application for disease control was also investigated. Brief reports on portions of these studies have been published previously (19,20).

MATERIALS AND METHODS

Disease survey. In the year before the study began, several orchardgrass seed-production fields were visited between February and June in the Willamette Valley to determine the severity and distribution of leaf spot diseases. Leaves were collected, and sections (1–2 cm long) were surface-sterilized by the procedure reported by Caldwell (2) and incubated in a moist chamber or on water agar at 15–20 C. Each year during this study, five to 10 growers' fields were visited in the spring and leaves were collected and cultured.

Koch's postulates. In greenhouse (15–20 C) experiments, 6-wk-old seedlings of orchardgrass (cultivar Potomac) were inoculated with an aqueous suspension of conidia (1×10^6 per milliliter) of *Rhynchosporium orthosporum* R. M. Caldwell and covered with a plastic bag for 3 days. Light-gray lesions developed in 10 days, leaves collapsed and became straw-colored 15 days after inoculation, and *R. orthosporum* was reisolated from leaf lesions. Lesions in inoculated leaves resembled lesions that developed in plants in the field.

Field plots. Orchardgrass cultivar Potomac was drill-seeded on 12 September 1983 in rows on 30.5-cm centers in a field of Woodburn fine-silt loam (pH 5.8) at the Hyslop Field Laboratory, Corvallis, OR. Soil was tested for nutrient content annually and limed according to field test recommendations. Plants were fertilized with 16-20-0 (NPK) (about 60 kg/ha of N in the fall and 120 kg/ha of N in the spring) to maintain vigorous growth and maximize seed production. Weed and insect problems were controlled with conventional practices. Individual plots (2.4 × 2.4 m) were established in this field planting.

Five years of the fungicide evaluations were done in the same planting. Each year, fungicide treatments were assigned to plots at random, and the experiment was arranged in a randomized complete block design. Plot treatments moved from location to location each year within the planting. Treatment means were based on six or 12 replications, as noted in the description of the experiment.

Fungicide applications and disease scoring were done at several plant growth stages (GS) based on a modification of the scale developed for cereal grains by Feekes (12). A GS value was established when 50% of the tillers were in a specific stage of growth. Growth states for orchardgrass and cereals are not directly comparable because of variable ranges in tiller maturity in orchardgrass. However, growth stages are described as follows: joint = GS 6 when stems are elongating and the first node of stem is visible at base of shoot; boot = GS 8 when the last (flag) leaf is visible but still rolled up and the seed head is swelling; heading = GS 10.1–10.5 when seed heads begin to emerge until emergence is complete; and anthesis = GS 10.5.1–10.5.5 when flowering begins at the base of the seed head until flowering is complete.

Fungicide treatments. In all studies, fungicides were mixed with water and applied at 374 L/ha (40 gal/acre) at 172.4 kPa (25 psi) with a spray boom fitted with 8,004 flat-fan nozzles. Control plots were sprayed with water.

During 1984–1986, plants were sprayed with chlorothalonil (Bravo 500) at 1,754 g a.i./ha (3 pt/acre), propiconazole (Tilt 3.6 EC) at 252 g a.i./ha (8 fl oz/acre), or captafol (Difolatan 80 S) at 1,345 g a.i./ha (1.5 lb/acre). Fungicides were applied at boot, heading, and/or anthesis. Each treatment had six replications.

In 1987, plants were sprayed with either chlorothalonil at 1,754 g a.i./ha, propiconazole at 252 g a.i./ha, or a tank mix of chlorothalonil + propiconazole (same rates) at GS joint, boot, and/or anthesis. Each treatment had six replications.

In 1988, fungicide rates were reduced to 1,170 g a.i./ha of chlorothalonil and 126 g a.i./ha of propiconazole and applications were made as a single fungicide or as a tank mix of the two; applications were made once (boot) or twice (boot and heading). Each treatment had 12 replications.

Disease assessment and yields. The collective areas of the plant with symptoms or signs of the pathogens were rated several times during the growing season. The last scores were taken at anthesis or when seeds were in the milky stage, usually about mid-June. Disease severity was rated in one of the following three ways: 1) in 1984, the number of primary and secondary branches in an inflorescence with girdling lesions were averaged for 10 heads for each plot; 2) during 1985–1987, the disease severity on a scale of 1–9 (1 = slight disease on lower leaves; 9 = severe disease with all leaves showing symptoms) was rated for each plot (a scoring system originally developed for leaf diseases of wheat) (14); or 3) in 1988, the percentage of leaf area damaged by diseases in the top four leaves of 10 tillers were averaged for each plot with a standard area key devised by James (10). Disease assessment dates were 22 June 1984, 5 June 1985, 4 June 1986, 29 May 1987, and 24 May and 8 June 1988.

After anthesis, seeds were collected from the field at 1- to 3-day intervals and dried in a microwave oven. When moisture contents reached 40–45% (dry-weight basis), seeds were harvested with a small-plot harvester, threshed, cleaned, dried to 10% moisture, and weighed. Harvest dates were 9 July 1984, 29 June 1985, 25 June 1986, 18 June 1987, and

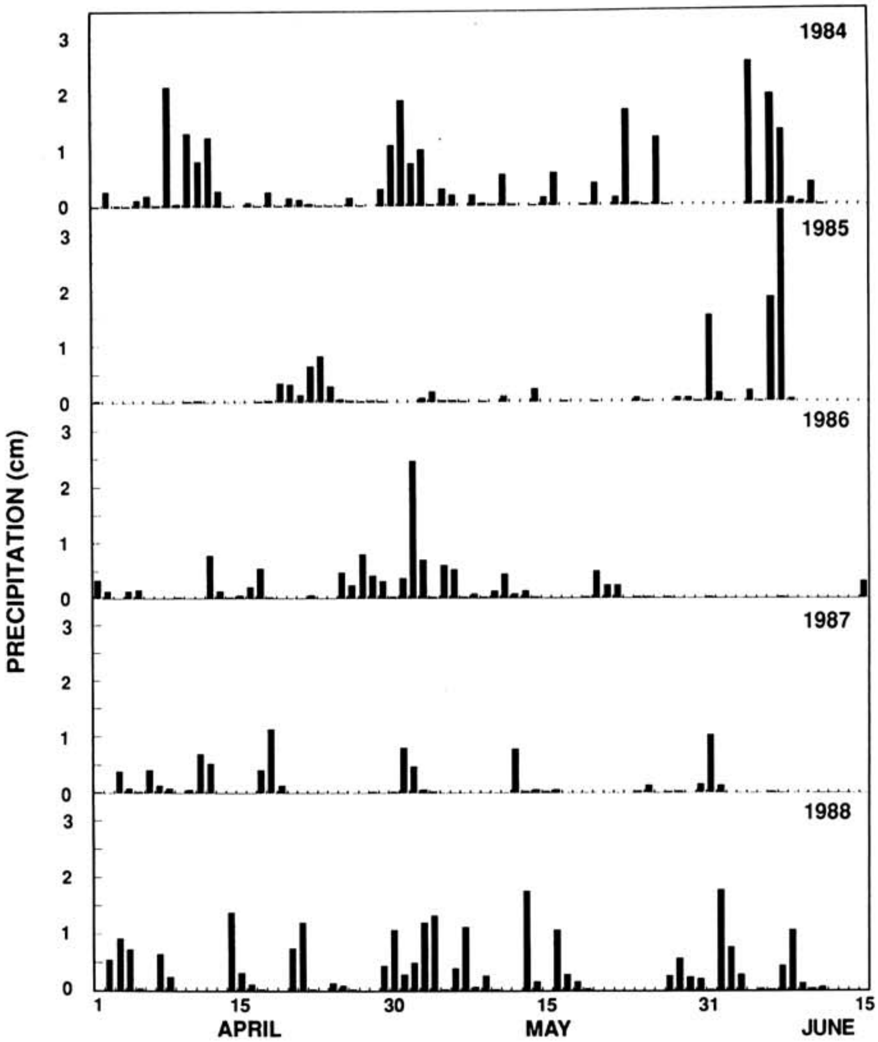

Fig. 1. Precipitation (cm) between 1 April and 15 June 1984–1988 at a field site where fungicides were applied to control foliar diseases in orchardgrass grown for seed.

29 June 1988. Seed yields were measured as grams of seed per plot and expressed as percent of control. After seed harvest, excess stems and leaves were removed from the plots with a flail harvester. No other postharvest management treatments were applied to these test plots.

Disease scores and seed yields were subjected to analysis of variance, and treatment means were compared using a protected LSD at $P = 0.01, 0.05$, or 0.1.

Precipitation and temperature. Data were provided by the Climatic Research Institute, Office of State Climatologist, Oregon State University, Corvallis. Observations were made at the Hyslop Field Laboratory for 24-hr periods ending at 0800. The weather station was located about 860 m from the test plots. The data are presented as daily total precipitation recorded between 1 April and 15 June for each of the 5 yr (Fig. 1) of the fungicide studies. Temperature data presented are combined average daily maximum and minimum temperatures recorded 1.07 m above the ground.

RESULTS

Disease observations. Three leaf spots (Fig. 2) occurred most frequently—eyespot (caused by *M. rubricosum*), scald (caused by *R. orthosporum*), and leaf streak (caused by *Cercosporidium graminis* (Fuckel) Deighton = *Scolicotrichum graminis* Fuckel). Stripe rust (caused by *P. striiformis* Westend. var. *dactylidis* Manners) and stem rust (caused by *P. graminis* Pers.:Pers. subsp. *graminicola* Z. Urban) were also found in some leaves in some years. These pathogens have been reported to occur in orchardgrass in Oregon (3,4,8,16).

In most years, the three leaf spot fungi occurred in sequence. *M. rubricosum* was first observed in February and generally remained confined to lower leaves throughout the remainder of the growing season. *R. orthosporum* was usually observed in mid-March on leaf blades and sheaths and continued to increase as leaves continued to emerge through mid-June. In some years, lesions caused by *R. orthosporum* developed on the primary and secondary branches of the panicles. *C. graminis* usually developed in lower leaves in late April and continued to infect newly emerged foliage until seed harvest. In these studies, *R. orthosporum* was the most frequent of the three leaf spot diseases observed, inducing premature death and desiccation of flag leaves and penultimate leaves. Lesions of *R. orthosporum* were also found in the orchardgrass panicles.

Fungicide trials. In 1984, one, two, or three applications of chlorothalonil or captafol resulted in significantly ($P = 0.05$) larger seed yields than nontreated controls (Table 1). Two or three applications of propiconazole resulted in significantly larger seed yields than the control. A single application of a fungicide was most effective when applied at either boot or heading. Fungicides applied at anthesis did not increase seed yield. In 1985, seed yields among all fungicide treatments were not significantly different from controls. In 1986, chlorothalonil applied at heading resulted in seed yields significantly larger than nontreated controls. Seed yields in plots treated with captafol or propiconazole were not significantly different from nontreated controls.

Disease scores in plants treated with chlorothalonil were significantly smaller than nontreated controls in 1984 and 1986 (Table 2). Sprays resulting in the lowest disease scores were applied at boot or heading. Disease scores in plants

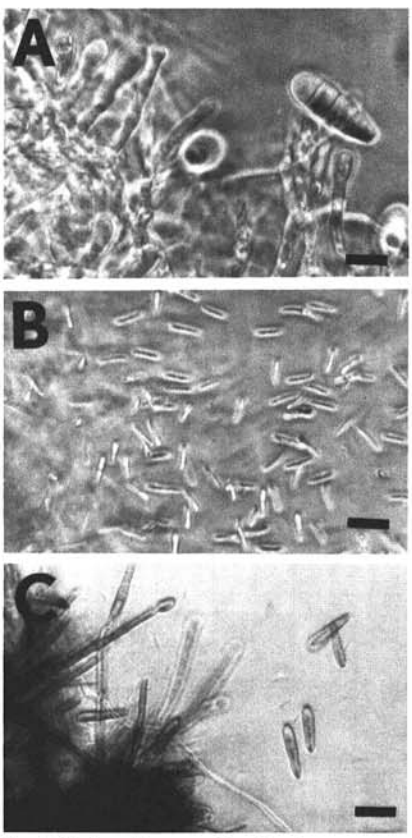

Fig. 2. Foliar diseases of orchardgrass grown for seed. **(A)** *Mastigosporium orthosporum* (conidia). Scale bar = 18 μm. **(B)** *Rhynchosporium orthosporum* (conidia). Scale bar = 21 μm. **(C)** *Cercosporidium graminis* (conidia). Scale bar = 29 μm.

Table 1. Seed yield (percentage of control) for Potomac orchardgrass treated at three growth stages with fungicides[a] to control three leaf diseases (scald, eyespot, and streak) in 1984, 1985, and 1986

Growth	1984			1985			1986		
stage	Ch	Ca	P	Ch	Ca	P	Ch	Ca	P
Control	100[b]	100	100	100	100	100	100	100	100
Boot (B)	127	110	103	94	103	102	108	116	96
Head (H)	130	116	117	90	104	99	114	108	96
Flower (F)	109	99	113	94	101	105	108	106	102
B + H	155	121	123	97	101	102	112	115	105
H + F	138	125	137	97	113	100	114	102	100
B + H + F	147	134	131	105	114	117	109	103	108
LSD $P = 0.05$	17	15	17	NS[c]	NS	NS	8	NS	NS

[a] Ch = chlorothalonil at 1,754 g a.i./ha, Ca = captafol at 1,345 g a.i./ha, and P = propiconazole at 252 g a.i./ha.

[b] Control seed yield (g/plot): 1984, Ch = 96, Ca = 103, P = 95; 1985, Ch = 190; Ca = 180; P = 173; and 1986, Ch = 259, Ca = 262, P = 267. Harvested on 9 July 1984, 29 June 1985, and 25 June 1986.

[c] NS = nonsignificant.

Table 2. Disease scores of Potomac orchardgrass treated at three growth stages with fungicides[a] to control scald, eyespot, and stripe in 1984, 1985, and 1986

Growth	1984[b]			1985[c]			1986[c]		
stage	Ch	Ca	P	Ch	Ca	P	Ch	Ca	P
Control	2.1	1.3	2.5	4.5	4.7	4.7	6.5	5.8	6.2
Boot (B)	0.8	0.5	2.5	4.5	4.7	4.8	5.0	5.3	5.5
Head (H)	0.4	0.4	2.1	4.3	4.5	4.5	5.2	5.7	6.0
Flower (F)	1.7	1.1	1.8	4.3	4.8	4.8	5.8	6.3	6.0
B + H	0.3	0.2	1.7	4.5	4.7	4.5	5.8	4.7	4.7
H + F	0.2	0.2	1.8	4.7	4.5	4.5	5.8	5.3	6.0
B + H + F	0.2	0.2	1.8	4.3	4.3	4.2	4.5	4.7	5.5
LSD $P = 0.05$	0.88	0.72	NS[d]	NS	NS	NS	1.25	NS	NS

[a] Ch = chlorothalonil, Ca = captafol, and P = propiconazole.

[b] Disease scoring: 1, 2, or 3 = few to moderate number of lesions on one, two, or three branches of the inflorescence, respectively; 4 = numerous lesions on all branches of inflorescence on 22 June 1984 at GS 11.1 (milk).

[c] Disease assessment: 1 = lesions confined to lower leaves, symptoms mild; 9 = lesions distributed on all leaves, symptoms severe on 5 June 1985 and 4 June 1986 at GS 10.5.3 (flowering complete).

[d] NS = nonsignificant.

treated with captafol at boot or heading were significantly smaller than nontreated controls in 1984. Disease scores in plants treated with propiconazole were not statistically different from nontreated controls during 1984–1986.

In 1987, seed yields and disease scores in plots treated with chlorothalonil alone or tank mixed with propiconazole were not statistically different ($P = 0.05$) from nontreated controls (Table 3).

In 1988, chlorothalonil or chlorothalonil + propiconazole applied at boot or boot + heading resulted in seed yields significantly ($P = 0.05$) larger than nontreated controls (Table 4). Leaf spot disease (mainly *R. orthosporum*) severity was rated twice. Plants assessed on 8 June in plots treated at boot or boot + heading with chlorothalonil alone or a tank mix of chlorothalonil + propiconazole had significantly ($P = 0.01$) less disease damage than nontreated controls.

Precipitation and temperature. At Hyslop Field Laboratory for April and May, long-term normal precipitation is 6.25 and 4.88 cm, respectively, and long-term average daily maximum and minimum temperatures are 9.5 and 12.6 C, respectively. Long-term normal conditions are 30-yr averages for 1951–1980 (G. H. Taylor, *personal communication*).

In 1984, precipitation was above normal in April and May (+2.41 and +4.45 cm, respectively) and average daily maximum and minimum temperatures were below normal in April and May (−0.55 and −0.86 C, respectively). Measurable precipitation occurred on 58 of 76 days between 1 April and 15 July (Fig. 1). These weather conditions were favorable for leaf disease development.

In 1985, precipitation was less than normal in April and May (−3.59 and −2.49 cm, respectively) and average daily maximum and minimum temperatures were higher than normal in April and May (+1.67 and +0.02, respectively). Precipitation was measurable on 39 of 76 days between 1 April and 15 June (Fig 1.). These weather conditions were less favorable for leaf disease development.

In 1986, more than normal precipitation occurred in May (+1.47 cm) and below normal precipitation occurred in April (−1.57 cm) and June (−2.26 cm). Precipitation in May (Fig. 1.) was sufficient for a moderate development in leaf diseases.

In 1987, precipitation in April and May (−2.29 and −1.32 cm, respectively) was below normal (Fig. 1), and temperatures in April and May (+2.1 and +1.9 C, respectively) were higher than normal. Scald, leaf streak, and eyespot was not severe in plants in the experiment nor in fields throughout the seed-producing areas.

In 1988, precipitation in April and May (Fig. 1) was above normal (+2.21 and +4.88 cm, respectively); precipitation occurred in 49 of 76 days, making conditions favorable for leaf spot development.

Table 3. Seed yield (percentage of control) and disease damage for Potomac orchardgrass treated in three growth stages with fungicides[a] to control scald, eyespot, and stripe in 1987

Growth stage	Disease score[b]			Seed yield[c]		
	Ch	P	Ch + P	Ch	P	Ch + P
Control	5.5	5.0	5.5	100	100	100
Joint (J)	4.6	5.6	4.0	103	106	111
Boot (B)	4.6	5.5	4.1	102	114	108
Head (H)	4.8	4.8	4.8	105	100	108
J + B	5.0	5.0	4.1	103	109	106
B + H	4.3	5.0	5.1	98	104	105
J + B + H	5.0	4.8	4.5	105	114	109
LSD $P = 0.05$	NS[d]	NS	NS	NS	NS	NS

[a] Fungicide rates: Ch = chlorothalonil at 1,754 g a.i./ha; P = propiconazole at 252 g a.i./ha; and Ch + P = 1,170 g a.i./ha + 126 g a.i./ha.
[b] Plants were scored 1–9 on 29 May 1987 at GS 11.1 (milk): 1 = lesions confined to lower leaves, symptoms mild; 9 = lesions distributed on all leaves, symptoms severe.
[c] Seed yield (g/plot) in control plots for Ch = 462; P = 423; and Ch + P = 438 (mean of six replications), harvested 18 June 1987.
[d] NS = nonsignificant.

Table 4. Severity of scald (caused by *Rhynchosporium orthosporum*) and seed yield for Potomac orchardgrass treated at two growth stages with chlorothalonil or propiconazole alone and in tank mix in 1988

Fungicide and rate/ha	Growth stage[a]	Leaf area damaged by scald[b] (%)		Seed yield[c] (% of control)
		24 May	8 June	
Control	. . .	29	62	100
Chlorothalonil (C) 1,170 g a.i.	Boot	15	30	124
Chlorothalonil (C) 1,170 g a.i.	Boot + heading	10	29	114
Propiconazole (P) 126 g a.i.	Boot	19	56	100
Propiconazole (P) 126 g a.i.	Boot + heading	25	57	105
C + P (1,170 + 126 g a.i.)	Boot	14	28	123
C + P (1,170 + 126 g a.i.)	Boot + heading	11	25	114
LSD 0.05		7.0	7.9	12.4
0.01		9.4	10.6	16.4

[a] Fungicides applied 28 April (boot) and 21 May (heading).
[b] Leaf area damaged by scald is the average of top four leaves for 10 tillers per plot and is the average of six replications scored 24 May (heading) and 8 June 1988 (milk).
[c] Seed yield is percentage of nonsprayed control (213 g/plot) harvested 29 June 1988 and is the average of 12 replications.

DISCUSSION

In 5 yr of field testing, data show fungicides control leaf spot diseases caused by *R. orthosporum*, *M. rubricosum*, or *C. graminis* in orchardgrass and increase seed yields in years when precipitation was above normal (1984, 1986, and 1988). In these years, fungicides (especially chlorothalonil) applied at boot or boot heading increased seed yields above nontreated controls. In 1985 and 1987 when precipitation was below normal, these leaf diseases were not severe, and fungicide applications did not result in higher seed yields.

Data obtained in May 1986, when precipitation was more than normal and leaf diseases were severe, indicate this month is critical for fungicide applications to obtain control of these diseases. In most years in the Willamette Valley in Oregon, flag leaves are emerging and seed heads (boot) are developing in late April and early May. Observations of weather conditions and weather trends during this time period are needed to provide timely application of fungicides.

Results reported here are in general agreement with seed yield and/or disease control data reported for fungicides applied for control of *M. rubricosum* in *D. glomerata* (13,18) and several foliar diseases of *L. perenne* (9). These data also indicate fungicides applied at anthesis do not provide sufficient control of leaf diseases to increase seed yield. This is similar to control of foliar diseases in *L. perenne* (9) and in small grains (5) where fungicides are not usually applied after GS 10 (spikes beginning to emerge from sheaths).

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