Systemic Fungicide Benodanil for Control of Pine-Oak Rust on Pine Seedlings in the Nursery

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ABSTRACT

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Benomyl and benodanil were tested for control of *Cronartium quercuum* f. sp. *banksianae* on five species of pine in a nursery bed. Both fungicides were applied as a soil drench either before or after inoculation with *C. quercuum* f. sp. *banksianae*. Symptoms were most frequent on control seedlings and those treated with benomyl but rare on seedlings treated with benodanil.

Pine-oak rust, caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *banksianae* Burdsall & Snow (=*Cronartium quercuum* (Berk.) Miyabe ex Shirai) is a serious problem on jack pine (*Pinus banksianae* Lamb.) and other species of hard pine growing in nurseries, plantations, and natural stands in the north central United States (6). In one nursery, 60% of the 2-yr-old jack pine were culled because of pine-oak rust (6).

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The culling procedure, however, does not remove seedlings with latent infections, so in some years, many diseased trees are planted. Using infected seedlings results in poor seedling survival and further rust infections if oaks (alternate host) are present within or near the planting site.

Fusiform rust, *C. quercuum* f. sp. *fusiforme*, has an infection biology similar to *C. quercuum* f. sp. *banksianae* (2,6). Ferbam (a protectant fungicide) is used commercially to control fusiform rust and has been used to control pine-oak rust (2,6,7). Effective control is only achieved when ferbam is applied repeatedly (as many as 30–50 applications) during basidiospore production (2).

Systemic fungicides have been evaluated for control of fusiform rust but only benodanil, triadimefon, and (to some extent) benomyl were effective when applied as a preplant soil treatment or foliar spray (3–5).

The objective of this study was to evaluate the effectiveness of benodanil and benomyl in controlling pine-oak rust on five species of hard pine in a northern nursery.

MATERIALS AND METHODS

Benodanil and benomyl were tested for effectiveness against *C. quercuum* f. sp. *banksianae* on the following five species of hard pine: *P. contorta* var. *latifolia* (lodgepole pine), *P. nigra* (Austrian pine), *P. ponderosa* (ponderosa pine), and *P. sylvestris* (Scots pine). Seeds of these species were sown in two nursery beds (1 × 4 m) at the Cloquet Forest Research Center, Cloquet, MN, on 7 May 1976. Each bed was divided into four sections (1 m^2) and planted with four replicates of each pine species. Seedling numbers varied among replicates, as listed in Table 1, and were generally highest for *P. banksiana*.

The fungicides benodanil and benomyl were applied as a soil drench at the following rates: benodanil, 200 mg a.i./L solution applied at 9.6 L/m^2, and benomyl, 200 mg a.i./L solution applied at 9.6 L/m^2. Only one fungicide was applied to each section of bed (except

Table 1. Pine seedlings treated with benomyl or benodanil that developed symptoms after inoculation with *Cronartium quercuum* f. sp. *banksianae*

Treatment	Species	Benomyl			Benodanil		
		Trees (no.)	Purple lesions[x] (%)	Galled[y] (%)	Trees (no.)	Purple lesions[x] (%)	Galled[y] (%)
28 Days before inoculation	*Pinus banksiana*	252	38.1	26.9 b	342	0.3	0.0 b
	P. contorta	132	22.7	15.9 b	150	0.0	2.1 b
	P. nigra	116	25.9	56.0 a	143	0.0	0.0 b
	P. ponderosa	82	20.7	33.7 a	154	0.0	0.0 b
	P. sylvestris	174	21.8	20.6 b	271	0.0	0.0 b
14 Days before inoculation	*P. banksiana*	223	48.0	53.2 a	402	0.0	0.0 b
	P. contorta	143	23.8	24.3 b	163	0.0	0.0 b
	P. nigra	115	24.3	59.5 a	118	0.0	3.4 b
	P. ponderosa	65	21.5	42.2 a	158	0.0	0.0 b
	P. sylvestris	182	34.1	39.3 a	318	0.0	0.0 b
14 Days after inoculation	*P. banksiana*	214	70.6	73.3 a	292	43.2	0.0 b
	P. contorta	120	29.2	39.2 a	174	21.8	0.0 b
	P. nigra	97	11.3	50.0 a	102	17.6	4.9 b
	P. ponderosa	58	13.8	41.1 a	148	8.1	13.3 b
	P. sylvestris	167	21.6	36.6 a	299	4.3	0.0 b
Control[z]	*P. banksiana*	103	69.9	57.7 a	462	80.7	55.9 a
	P. contorta	86	61.6	44.0 a	130	60.8	69.5 a
	P. nigra	103	27.2	53.9 a	130	49.2	73.6 a
	P. ponderosa	71	43.7	47.1 a	178	59.6	59.1 a
	P. sylvestris	121	43.8	35.0 a	345	49.9	46.9 a

[x]Results 42 days after inoculation with *C. quercuum* f. sp. *banksianae*.
[y]Results 407 days after inoculation with *C. quercuum* f. sp. *banksianae*. Values in the same column followed by a common letter are not significantly different based on analysis of variance ($P = 0.05$).
[z]Control: fungicides not applied but seedlings inoculated with *C. quercuum* f. sp. *banksianae*.

controls) either 14 or 28 days before or 14 days after inoculation with *C. quercuum* f. sp. *banksianae*. These seedlings were inoculated in situ about 45 days after germination, while still in the cotyledon and early primary needle phase of growth.

For inoculation, naturally infected red oak leaves in the telial stage were placed on a 1-cm^2-mesh wire screen (1 m^2) suspended about 10 cm above the seedlings in a chamber similar to one described previously (1). Seedlings were maintained at a high relative humidity during the 44-hr inoculation period.

All seedlings were maintained in the treated nursery beds through two growing seasons and evaluations were made 42 and 407 days after inoculation. Data were analyzed by analysis of variance.

RESULTS

All five species of pine were susceptible to *C. quercuum* f. sp. *banksianae* as shown by the controls (Table 1). Infected seedlings had well-developed purple lesions on the main stem 42 days after inoculation, and by 407 days, stem swellings (galls) were very prominent. Purple lesions were first observed near the base of infected needles, and galls usually developed at this site.

Compared with benodanil treatments, benomyl treatments were not effective; purple lesions and galls were most frequent on controls and on seedlings treated with benomyl. Purple lesions and galls rarely developed on seedlings treated with benodanil before inoculation, but both lesions and galls developed on some seedlings treated 14 days after inoculation. These galls continued to develop on a low percentage of seedlings of *P. nigra* and *P. ponderosa* (4.9 and 13.3%, respectively) but did not develop on seedlings of *P. banksiana*, *P. contorta*, or *P. sylvestris*.

There were no visual phytotoxic effects observed on seedlings treated with benodanil or benomyl at the rates used in this study.

DISCUSSION

Benomyl did not provide adequate control of *C. quercuum* f. sp. *banksianae* but may have slowed lesion and gall development on some pine species. These results are consistent with previously published data on the effectiveness of benomyl on *C. quercuum* f. sp. *fusiforme*.

Benodanil consistently prevented purple lesions and almost all gall development when applied before inoculation. Benodanil applied 14 days after inoculation restricted purple lesion and gall development (at least through two growing seasons—407 days), indicating that it may have eradicative capabilities.

In the nursery areas of Minnesota, the peak period of basidiospore production and dissemination for *C. quercuum* f. sp. *banksianae* is limited to about a 2-wk period in mid-July (D. R. Bergdahl and D. W. French, *unpublished*). Prolonged moist weather conditions are also necessary for basidiospore production and infection at that time. Knowing the peak period of basidiospore production and the capabilities of benodanil, a single application of this systemic fungicide at the proper time may be all that is necessary to effectively control *C. quercuum* f. sp. *banksianae* in Minnesota nurseries.

Both benodanil and triadimefon are effective in controlling *C. quercuum* f. sp. *fusiforme*, and because benodanil is not currently in commercial production, triadimefon should be evaluated as a control for *C. quercuum* f. sp. *banksianae* on hard pines in northern forest nurseries.

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