

# Fungicidal Control of Shoot Blight Caused by *Sphaeropsis sapinea* on Red Pine Nursery Seedlings

M. A. PALMER and T. H. NICHOLLS, Research Plant Pathologists, North Central Forest Experiment Station, and C. F. CROGHAN, Plant Pathologist, Northeastern Area, State and Private Forestry, USDA Forest Service, St. Paul, MN 55108

## ABSTRACT

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Benomyl, thiophanate-methyl, and fentin hydroxide were evaluated for control of shoot blight caused by *Sphaeropsis sapinea* on second- and third-year *Pinus resinosa* seedlings. Only benomyl was effective. Benomyl applied twice 14 days apart during August allowed 4% disease incidence in treated first-year seedlings versus 34% in untreated controls in the most severe of three annual tests. Somewhat better control was achieved with five or seven applications from July through August or from June through August, respectively. Severe infection occurred during the second year of growth if seedlings were not protected during the first year. Four benomyl applications at 14-day intervals during budbreak and shoot elongation (late April through early June) allowed only 4% incidence of second-year infection versus 33% in untreated controls. Where benomyl was applied during the first but not the second year of growth, incidence of shoot blight during the second year was 5.2%. Least infection (2.7%) occurred when benomyl was applied for two consecutive years.

Additional key words: *Diplodia pinea*

Shoot blight caused by *Sphaeropsis sapinea* (Fr.) Dyko & Sutton (= *Diplodia pinea* (Desm.) Kickx) affects native and exotic conifers throughout the world. In the United States, this disease occurs primarily in ornamental and shelterbelt plantings of exotic pines (6,8) and on native conifer seedlings in forest tree nurseries (2,10).

In the north central United States, *S. sapinea* has caused losses of red pine (*Pinus resinosa* Ait.) seedlings in forest tree nurseries. In 1981, 35% of the first-

year seedling crop was affected with shoot blight in one Wisconsin nursery (8). Infected cones from surrounding *P. resinosa* windbreaks and infected seedlings within the seedbeds were identified as the major inoculum sources (5). Spores of *S. sapinea* were disseminated by rain splash from these sources throughout the growing season.

Fungicide application programs have been developed to control shoot blight in ornamental and shelterbelt plantings (6,7,9). Timing of fungicide applications is critical for successful control. Peterson (6) determined that shoots of *P. nigra* in Nebraska were susceptible for a 2-wk period when buds were opening and shoots were elongating. Two applications of 5-5-50 Bordeaux mixture during this period provided control. Benomyl controlled shoot blight on *P. nigra* in New York when applied at budbreak and at 10 and 25 days later (9).

Seedlings of *P. resinosa* are commonly

grown in the nursery for 3 yr. Budbreak and shoot elongation of second- and third-year seedlings occur from late April through early June (5). Fungicides should be applied during this period to protect the highly susceptible new shoots and needles (1,6); however, the appropriate time to apply fungicides to first-year seedlings is not known. In this region, autumn-seeded stock emerges in late May of the following year. Most diseased seedlings have apical buds (5). Because *S. sapinea* kills tissues soon after penetration (6), infection probably occurs during mid-summer when buds are forming. From this information, an effort was begun to develop a fungicide control program for shoot blight of nursery seedlings.

## MATERIALS AND METHODS

Fungicide evaluations were conducted at the Griffith State Nursery, Wood County, and the Wilson State Nursery, Grant County, in Wisconsin. Seedbeds at the Griffith Nursery were surrounded by windbreaks of mixed conifer species and hardwoods. Windbreaks at Wilson Nursery were almost exclusively *P. resinosa*. Seedlings had been infected by *S. sapinea* in both nurseries (8).

**Shoot blight control in second- and third-year seedlings.** Fungicide sprays containing suspensions of 0.3% a.i. of thiophanate-methyl (Topsin-M), benomyl (Benlate 50WP), or fentin hydroxide (Duter) were applied to plots (31 × 1.2 m) of second- or third-year seedlings. The fungicides were selected for field testing because they had demonstrated activity against *S. sapinea* in vitro (M. A. Palmer, unpublished). Control plots were not sprayed. A randomized block design was used with eight replicates of each

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treatment. Fungicides were applied with hand-held canister sprayers on 11 and 26 May and 11 and 25 June 1981. Treatments were evaluated on 16 September. An analysis of variance was performed on the square-root transformation of the number of symptomatic and dead seedlings per plot. In all evaluations, disease was confirmed by identification of conidia of *S. sapinea* from pycnidia produced on shoots and needles. The Student-Newman-Keuls test was used to compare treatment means.

**Shoot blight control in first-year seedlings.** Evaluations were conducted in 1981 and 1982 at the Wilson Nursery in three sections that each contained nine seedbeds 164 × 1.2 m. Benomyl was applied to six seedbeds in each section at a rate of 1.1 kg a.i./ha with a hydraulic sprayer. The remaining three seedbeds were not treated. Each section was assigned one of three benomyl application schedules at 14-day intervals: 1) from June through August (seven applications), 2) from July through August (five applications), or 3) in August only (two applications). Treatments were evaluated on 17 September 1981 and 2 September 1982 by counting the diseased and healthy seedlings in 20 randomly selected plots (0.2 × 1.2 m) in each treated area and in 60 such plots in untreated seedbeds. The design of this experiment precluded statistical analysis of first-year data. An analysis was performed on disease occurring during the second year, as described later.

In 1983, the experiment was repeated with an application rate of 0.6 kg a.i./ha. A randomized block design was used with three replicates of each spray schedule. Treatments were evaluated on 13 October as described previously, except 45 plots per treatment were examined. Data collection methods for this and the following experiments were changed from those used for fungicide evaluations in second- and third-year seedlings because the number of first-year seedlings per plot differed widely among plots. The varying seedbed densities were apparently due to a combination of irregular seeding and mortality from damping-off. Therefore, a different data transformation was necessary to satisfy homogeneity of variance assumptions for analysis of variance. An analysis of variance was performed on the arc sine transformation (3) of the proportion of diseased seedlings per plot. The Student-Newman-Keuls test was used to compare treatment means.

To relate spray schedule results to phenological development of first-year seedlings, 10 seedlings were examined and descriptions of seedling development recorded each week from 25 May to 5 September 1983.

**Two-year program for shoot blight control.** In 1983, evaluation areas were established in the beds of second-year

seedlings used for benomyl evaluations in 1982. Low incidence of disease occurred in beds where benomyl had been applied the previous year, but severe disease occurred in untreated beds. Benomyl was applied to entire seedbeds with a hydraulic sprayer at a rate of 1.1 kg/ha. One of the following application programs was assigned to one or more seedbeds in each of the three sections: benomyl applied in 1982, not applied in 1983; benomyl applied in 1982 and 1983; benomyl not applied in 1982 or 1983 (control); and benomyl not applied in 1982, applied in 1983. A randomized block design was used with three replicates of each treatment. Fungicide was applied on 25 April, 9 and 23 May, and 6 June. Disease in second-year seedlings in each treatment was evaluated on 14 October by counting diseased and healthy seedlings in 45 randomly selected plots (1.2 × 0.2 m) per treatment. Because of heterogeneity of variance between data from treatments and data from the control, the Student's *t* test, adjusted for unequal variances (11), was used to compare each treatment mean with the control mean. No heterogeneity of variance was detected in data from the three treatments. Therefore, an analysis of variance, performed on the arc sine transformation (3) of the proportion of diseased seedlings per plot, followed by the Student-Newman-Keuls test was used to make comparisons among treatment means.

Cumulative seedling losses for the 2-yr period were also calculated for each treatment. Disease incidence data from the 1982 first-year seedling fungicide evaluations were combined with incidence data obtained in the experiment described previously. Student's *t* test was used to make individual comparisons between each treatment mean and the control mean.

## RESULTS

**Shoot blight control in second- and third-year seedlings.** Fungicide applications on second-year seedlings were ineffective at Griffith Nursery, and only benomyl suppressed infection of second-year seedlings at Wilson Nursery (Table 1).

**Table 1.** Effectiveness of three fungicides for control of shoot blight caused by *Sphaeropsis sapinea* on second- and third-year *Pinus resinosa*

Fungicide treatment <sup>1</sup>	Number of diseased seedlings per plot <sup>2</sup>			
	Griffith Nursery		Wilson Nursery	
	Second-year	Third-year	Second-year	Third-year
Benomyl	12.1 a	5.8 a	7.6 a	28.6 a
Thiophanate-methyl	10.8 a	11.9 b	10.6 b	56.3 b
Fentin hydroxide	24.1 b	22.3 c	10.5 b	76.5 c
No treatment	12.5 a	33.3 d	15.0 b	74.4 c

<sup>1</sup>A 0.3% a.i. fungicide spray was applied on 11 and 26 May and 11 and 25 June 1981.

<sup>2</sup>Values are averages of eight replicates. Means in columns followed by the same letter are not significantly different ( $P = 0.01$ ) according to the Student-Newman-Keuls test. About 1,100 seedlings per plot.

At both nurseries, benomyl provided significantly ( $P = 0.01$ ) better shoot blight control than the two other fungicides tested in beds of third-year seedlings (Table 1).

**Shoot blight control in first-year seedlings.** All three application schedules suppressed infection by *S. sapinea*. In 1981, disease incidence ranged from 0.1 to 4% in beds treated with benomyl (Table 2). Among treated beds, most infection occurred in seedbeds receiving only two benomyl applications in August. Less disease was observed when five or seven applications were made. Similar results were obtained in 1982.

Significant differences ( $P = 0.01$ ) among treatments were observed in 1983 when benomyl was applied at 0.6 kg/ha; however, disease levels were lower than in previous years. Buds were forming on first-year seedlings during the fungicide application period and were fully developed by mid-August.

**Two-year program for shoot blight control.** The most effective control of shoot blight of second-year seedlings was achieved when benomyl was applied in both 1982 and 1983 (Table 3). Severe second-year infection (33%) occurred in beds where no fungicide was applied during the 2-yr period. Only 4.3% of second-year seedlings became diseased when benomyl was applied to beds that had sustained severe disease during the first year.

Applications of benomyl during the first year reduced infection for the entire 2-yr period (Table 3). Least disease (2.7% incidence) occurred in beds where benomyl was applied for two consecutive years. When fungicide applications were made only during the first year, 5.2% infection occurred. About 42% of the seedling crop was infected after 2 yr in seedbeds where benomyl was not applied.

## DISCUSSION

Fungicidal control of shoot blight caused by *S. sapinea* was most successful when initiated during the first year of growth. The most effective control was obtained with seven benomyl applications from June through August, although only slightly more infection occurred with five or two applications. On the basis

**Table 2.** Effectiveness of three benomyl application schedules for control of shoot blight caused by *Sphaeropsis sapinea* on first-year *Pinus resinosa* at the Wilson State Nursery in Wisconsin

Application schedule <sup>x</sup>	Seedlings diseased (%)		
	1981 <sup>y</sup>	1982 <sup>y</sup>	1983 <sup>z</sup>
June–July (seven applications)	1.3	0.5	0.03 a
July–August (five applications)	0.2	2.2	0.03 a
August (two applications)	4.0	4.9	0.70 b
No treatment	34.4	15.4	2.40 c

<sup>x</sup> Benomyl applied at a rate of 1.1 kg/ha in 1981 and 1982, and at 0.6 kg/ha in 1983.

<sup>y</sup> Values are averages of 20 plots per treated area and 60 plots in untreated areas. Number of seedlings per plot ranged from 15 to 108. Statistical analysis not performed on these data.

<sup>z</sup> Values are averages of 45 plots per treatment. Number of seedlings per plot ranged from 12 to 132. Values followed by different letters are significantly different ( $P = 0.01$ ) according to the Student-Newman-Keuls test.

**Table 3.** Effectiveness of four benomyl application programs for 2-yr control of shoot blight caused by *Sphaeropsis sapinea* on *Pinus resinosa* at the Wilson State Nursery in Wisconsin

Year fungicide applied <sup>x</sup>		Seedlings diseased (%)	
		1983 <sup>y</sup>	1982 and 1983 <sup>z</sup>
1982	1983		
No	No	33.0 d	42.2 d
No	Yes	4.3 b	18.2 c
Yes	No	1.3 b	5.2 b
Yes	Yes	0.2 a	2.7 a

<sup>x</sup> Benomyl applied to second-year seedlings at a rate of 1.1 kg/ha on 25 April, 9 and 23 May, and 6 June 1983. Number of seedlings per plot ranged from 15 to 70.

<sup>y</sup> Values are averages of 45 plots per treatment. Values in columns followed by the same letter are not significantly different ( $P = 0.01$ ). The Student-Newman-Keuls test was used for comparisons among treatment means. Student's *t* test was used to compare each treatment with the control mean.

<sup>z</sup> Cumulative percent disease calculated from first- and second-year seedling fungicide evaluations. Comparisons between each treatment mean and the control mean were made with Student's *t* test.

of comparisons among treatments at Wilson Nursery, the additional three to five applications would have protected an additional 81,000–117,000 seedlings in 1981. These seedlings would have sold for \$7,000–10,000 at 3 yr of age. The nursery manager, Richard Camp, estimated that the cost of each benomyl application was about \$125, so the additional applications would have been cost-effective.

It is important to suppress infection of first-year seedlings in seedbeds, because both infected seedlings and cones in windbreaks are important sources of inoculum of *S. sapinea* in nurseries (5). Disease gradients in beds of first-year seedlings demonstrated that infected cones in windbreaks were the primary source of inoculum in forest tree nurseries (5). During the second year, infected seedlings in seedbeds were an important inoculum source. Protection of seedlings by benomyl during the first year resulted in low levels of disease during the second year. The lower incidence of disease can probably be attributed to suppressed inoculum buildup. However, an alternative explanation for the reduced disease in nonsprayed beds is that the protective effects of benomyl last more than 1 yr. Kais (4) found that a benomyl root dip of *P. palustris* seedlings controlled *Scirrhia acicola* for the first 2 yr after outplanting.

The lack of a control program during the first year does not preclude a successful program during the second year. Seedbeds not treated during the first growing season but treated during the second had only 4.3% incidence of shoot blight versus 33% in untreated controls. Therefore, nurseries that do not have an ongoing shoot blight control program but observe losses in first-year beds can expect a fungicide program begun during the second growing season to protect the remaining stock. The best 2-yr control was achieved when benomyl was applied for two consecutive years.

Four applications of benomyl beginning on 11 May provided satisfactory shoot blight control on third-year seedlings. Infection in treated beds probably could have been suppressed further if fungicide applications had begun earlier. Peterson (6) found shoots

of *P. nigra* to be most susceptible immediately after budbreak. Budbreak of third-year seedlings in the north central area begins in late April (5).

Shoot blight caused by *S. sapinea* can be controlled successfully in forest tree nurseries with a combination of management techniques. Sources of inoculum, including windbreak trees with infected cones or shoots and infected seedlings in seedbeds, can be reduced or eliminated (5). If shoot blight is a continuing problem in the nursery, fungicide should be applied during the first year of growth.

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