Phenology and Control of Endocronartium harknessii in Pennsylvania

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ABSTRACT

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Sporulation of *Endocronartium harknessii* is synchronized with host development (Scots pine, *Pinus sylvestris*). The peridermioid teliospores are disseminated from the beginning of needle emergence from the fasicle sheath until the needles have reached about 75% of maximum length. A single application of maneb (3.6 g/liter = 3 lb per 100 gallons of water) at the beginning of spore release prevented infection of Scots pine Christmas trees. Three systemic fungicides tested gave negative results.

Pine-pine gall rust (western gall rust, Woodgate gall rust), caused by *Endocronartium harknessii* (J. P. Moore) Y. Hiratsuka, is widespread in northern Pennsylvania and is causing serious losses in some Scots pine (*Pinus sylvestris* L.) Christmas tree plantations. The fungus is an autoecious endocyclic rust. During the spring it produces a single crop of wind-disseminated peridermioid teliospores (spores which morphologically are aeciospores, but functionally are teliospores) (1) which infect the current year's young shoots or needles.

The only control of this pathogen to date has been to rogue and burn infected trees. This is an economic disaster if the incidence of severely galled trees is high; the incidence of such trees has reached 75% in some plantations in Pennsylvania.

Peterson (2) studied spore release by this pathogen in central Nebraska; spores were released as early as 8 May, and although spore release continued until late June, 80% of the spores had been released by the end of May.

Our observations from northern Maryland to northern Pennsylvania indicated that the period of sporulation was relatively brief and varied with seasonal temperatures and/or latitude. Thus, the timing of application of protectant fungicides would be critical, making it necessary to develop a system by which the grower could determine the proper spray date depending upon local conditions.

Rust fungi which attack the young current year's foliage of conifers appear to have degree-day relationships similar to those of their hosts so that sporulation coincides with the period of susceptibility of the hosts (3). The following studies were done (i) to relate seasonal development and sporulation of the fungus to the phenology of Scots pine, and (ii) to evaluate the effectiveness and timing of several fungicides for control of this pathogen on Scots pine.

MATERIALS AND METHODS

From April to July of 1973, 1974, and 1975, 50 infected Scots pines bearing from 20 to over 3,000 galls each were examined in affected plantations in McKean County, Pennsylvania. The stage of sporulation was recorded together with the stage of candle (current year's shoot) and needle elongation.

On 1 May 1973, 15 pairs of Scots pines 1.0-1.5 m tall were selected for similarity in height, and intensity and age of infection. All trees bore sporulating galls as well as many small galls which had not yet produced spores. The trees were tagged and numbered. Fungicide spray treatments were applied to one randomly selected tree of each pair.

Three systemic fungicides were used: benomyl 50% WP (Benlate) at the rate of 3.6 g/liter (3 pounds of commercial product per 100 gallons) of water; oxycarboxin 75% WP (Plantvax) at rates of 0.6, 3.6, and 12.0 g/liter (0.5, 3.0, and 10.0 pounds of commercial product per 100 gallons, respectively) of water; and Dowco 261 (chemical name not released; Dow Chemical Co., Midland, Michigan) at the rate of 3.6 g/liter (3 pounds of commercial product per 100 gallons) of water. All fungicides were applied with a small hydraulic sprayer to the foliage until run-off. Each treatment was applied to three trees.

Forty more pairs of infected trees were selected in a similar manner. One tree of each pair was sprayed with maneb 80% WP fungicide at the rate of 3.6 g/liter (3 pounds per 100 gallons) of water. Trees were sprayed until run-off. Four different combinations of spray dates were used; 10 pairs of trees were treated for each spray date. In September 1974 three randomly selected pairs of trees from each treatment were felled. The length of every 2-

year-old twig on each tree was measured, and the number of galls on each twig was counted (Table 1).

RESULTS

Phenology of host and pathogen.—Observations in 1973 on the phenology of Scots pine and the pathogen showed the following: By 27 April candles were beginning to elongate but were less than 25% of maximum length; peridia were visible on some galls. On 10 May candles were less than 50% of maximum length; peridia were visible on all galls and a few peridia were beginning to rupture. On 15 May candles had elongated to about 75% of maximum length; needles were beginning to emerge from the fasicle sheath; peridia were ruptured on most galls. On 22 May needles had elongated to 25 to 50% of maximum length; many of the galls were almost completely devoid of spores. On 3 June the candles were fully elongated; needles were about 75% of maximum length; most galls had very few spores remaining and the telia were being overgrown by white mycelium.

In 1974 the phenology was as follows. On 1 May the candles were elongating but were less than 75% of maximum length; peridia were visible on about 50% of the galls. On 21 May the candles had achieved 75% of maximum length; needles were emerging from the fasicle sheaths; peridia were visible on all galls and some peridia were rupturing. On 28 May the needles were 25 to 50% of maximum length; all peridia were ruptured and most galls were releasing spores; some galls were already nearly devoid of spores. On 4 June the needles were 50 to 75% of maximum length; some spores still remained on the galls but most telia were being overgrown by white mycelium. On 9 July the candles and most needles were fully elongated; only one of 3,997 galls still contained viable spores.

In 1975 the phenology was as follows. On 15 May buds were just beginning to break; a few peridia were visible on a few galls. On 30 May the candles were about 66% of maximum length; needles were emerging from the fasicle sheaths; peridia were rupturing on most galls. On 13 June the candles were about 85 to 90% elongated; needles were 50 to 75% of maximum length; most galls were already devoid of spores and were being overgrown by white fungus mycelium.

Spring temperatures in 1973 and 1974 were close to normal (+6 and −42 growing degree-days on 14 May and 13 May, respectively) whereas the spring of 1975 was one of the coldest on record, with seasonal development of plants delayed by about 3 weeks (−142 growing degree-days on 12 May) according to data collected by the Pennsylvania Crop Reporting Service. In all 3 years, however, development of the rust fungus was closely synchronized with host development, thus confirming our preliminary observations and affording a basis for the timing of fungicidal sprays.

Peridia of the peridermioid telia become evident just as the buds break and the candles begin to elongate. Telia continue to develop as the candles elongate. As the candles reach 50% of maximum length, the needles begin to break through the fasicle sheath. As this occurs, the peridia on most galls rupture, releasing the spores for wind dissemination. By the time the needles have reached about 50% of their maximum length, most of the spores have been released. The telia often are then overgrown by a whitish mycelium of septate hyphae. This latter fungus may be a hyperparasite, since spores from telia overgrown by this fungus germinate poorly or not at all.

Chemical control.—All trees sprayed with the systemic fungicides and paired unsprayed check trees were examined on 28 May 1974 at the peak of sporulation of the pathogen. The fungicides had no effect upon sporulation. Galls sporulating in 1973 produced abundant spores in 1974; young galls not sporulating in 1973 also produced abundant spores in 1974. There were no discernible differences among treatments, and none differed from the unsprayed check trees. There was no discernible phytotoxicity. Although only limited numbers of trees were involved, the results indicate that the three chemicals lack sufficient eradicative effect to be useful under normal management practices.

Maneb applied 21 May as the needles broke through the fasicle sheath (and as the peridia ruptured and released the spores) greatly reduced the incidence of infection. Trees sprayed on this date had 0.2 to 0.3 galls per meter of twig, in comparison to 14.3 galls per meter of twig on nonsprayed check trees (Table 1). Trees sprayed only on 7 May (somewhat before the period of major spore release) and those sprayed on 4 June (somewhat after the period of major spore release) had significantly more galls than those sprayed on 21 May, but significantly fewer galls than nonsprayed check trees (Table 1). The total number of galls on 2-year-old twigs ranged from 2 to 85 (average 77) per tree for all sprayed trees, and 704 to 1,394 (average 1,089) per tree for the paired nonsprayed check trees.

TABLE 1. Incidence of galls caused by *Endocronartium harknessii* on Scots pine sprayed with maneb

Spray dates	Average number of galls/meter of twig[a]
21 May	0.2
7, 21 May, 4 June	0.3
7 May	0.6
4 June	0.8
Nonsprayed check trees	14.3

[a]Means enclosed with brackets not significantly different at $P = 0.05$ (Student's t test).

DISCUSSION

Dense dead weeds and grass prevented good spray coverage of the bottom whorls of branches; the majority of the galls formed on the lower branches in sprayed trees, whereas the galls were nearly uniformly distributed among the branches on the nonsprayed trees.

Severely galled trees are nonmerchantable and under good management practices are rogued. However, until a tree is so severely affected that stunting, chlorosis, and witches' brooming are evident, it often is difficult to detect infection in dense, tightly sheared Christmas trees. Until all such trees are located and destroyed, a protectant fungicide could be applied to prevent infection of the remaining healthy trees. Further, if many trees in the plantation are only lightly infected, a fungicidal spray could be used to prevent increase in galling until they reached cutting age.

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