Infection Periods in Naemacyclus Needlecast of Scots Pine

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ABSTRACT

MERRILL, W., B. R. KISTLER, L. ZANG, and K. BOWEN. 1980. Infection periods in Naemacyclus needlecast of Scots pine. Plant Disease 64:759-761.

Isolations from 5 yr of complements of Scots pine needles from needle emergence from the fascicle sheath until casting 16–18 mo later showed three infection periods by *Naemacyclus minor*. Period one extended from the time of full needle elongation (about mid-July) until late August, period two from early November to early December, and period three from mid-April until late August of the following year. During 5 yr of study, periods one and three were periods of major infection, with greatest infection occurring in period three. Increase in level of infection during period two usually was not significant, although fruit body formation was most conspicuous at this time. The incubation period varied from 2 to 16 mo, depending on when the needles were infected.

Naemacyclus minor Butin (2) needlecast of *Pinus sylvestris* (Scots pine) has caused significant quality losses in Pennsylvania Christmas tree plantations for a number of years (5,7,8,11). We have found this disease also in Ohio, West Virginia, and New York, and we believe that the pathogen has been reported previously in California, Colorado, Massachusetts, and Michigan as *N. niveus* (1,3,4,10).

Often confused with feeding damage of the spotted pine aphid *Eulachnus agilis* or with "premature senescence," symptoms of *N. minor* infection begin to develop in late September when needles from previous years turn yellow with prominent, transverse brown bars (7,8,11,14). Casting of these needles and development of apothecia occur from late October through December (7,8,11,14). Symptoms usually are uniform over the crown, in contrast with other needlecasts, where disease severity usually decreases from the lower to the upper crown.

Little is known of the disease cycle. We originally reported that infection occurred in early summer, just after needle elongation, and again in November (8). Because viable ascospores are present in affected plantations throughout most of the year (8), it seemed possible that infection might occur almost any time environmental conditions were favorable. This study was conducted to further elucidate the time of infection. Preliminary reports have been made (6,13).

Contribution 1141, Department of Plant Pathology, The Pennsylvania State Agricultural Experiment Station. Approved for publication as Journal Series Paper 5886.

0191-2917/80/08075903/$03.00/0

MATERIALS AND METHODS

Symptomology and disease development were observed over a 5-yr period in *N. minor*-affected, commercial Scots pine Christmas tree plantations in Centre, Clearfield, McKean, Sullivan, and Tioga counties, PA. The trees, primarily of French and Spanish provenances, were 6–13 yr old.

In each plantation, one shoot was removed from the crown of each of 20 randomly chosen trees at 14- to 21-day intervals beginning in June. The trees were known to be susceptible because of symptom development the previous year. Ten needles from each year's complement were randomly removed from each shoot; surface-sterilized in an 0.52% aqueous solution of sodium hypochlorite for 90 sec; washed in sterile, distilled water; cut into three pieces; and placed on 2% acid malt extract agar (20 g of malt extract, 15 g of powdered agar per liter of distilled water, plus 1.0 ml of concentrated lactic acid per liter of autoclaved medium). These isolations were incubated in dim fluorescent light at 21 C for 21 days. The resulting fungal colonies were compared with known isolates of *N. minor*, and the number of infected needles of a total of 200 was recorded.

Based on the availability of inoculum in plantations and weather conditions favorable for infection (8), the time from complete needle elongation (about mid-July) until the end of symptom development on those needles (about 30 November the following year) was divided into three infection intervals: period one, 15 July–30 August; period two, 1 November–30 December; and period three, 15 April–30 August.

Isolation frequencies over these three intervals were compared using Student's t test with $P = 0.05$. The isolation studies involved 5 yr of complements of needles from the time each complement emerged

from the fascicle sheaths in early June until symptom development up to 16 mo later.

RESULTS AND DISCUSSION

In these and previous studies (7,8,11), symptom development on needles 1 yr old or older began in mid-September and lasted until November. Sporulation on these needles began in mid-October; most of the apothecia had formed by the end of December. Most infected needles were cast from late October to the end of December, although some needles bearing apothecia remained attached to the tree throughout the winter and were cast the following spring. The fungus overwintered as mycelium or apothecia in the needles.

Figure 1 shows disease progress curves for infection of the 1976 and 1977 needles in a Dushore (Sullivan County) plantation; the 1976, 1977, and 1978 needles in a Curwensville (Clearfield County) plantation; and the 1978 needles in a Mingoville (Centre County) plantation. Initial portions of the curves for the 1976 and 1978 needles in the Curwensville plantation were virtually superimposed on the other curves and have been omitted for clarity. The occasional decreases in isolation frequency are believed to be caused by sampling error.

In all years, *N. minor* was first isolated from newly emerged needles in July. About 10% foliar infection occurred in period one. This level of infection increased somewhat in period two, but the increase was not significant except in the Dushore plantation, where warm weather in December 1977 allowed about 30% fall infection.

In all years, the level of infection increased to 50–90% in period three. This spring infection period is the major infection period in Pennsylvania. Indeed, if the data in Fig. 1 are superimposed on the same time scale (Fig. 2), it can be seen that most infection occurred over a 6- to 8-wk period from late April to mid-June. This similarity in disease progress curves is remarkable considering that these data are from plantations in three different climatic regimes in the state over 3 yr.

All data were pooled, and percentage of foliar infection was regressed against time measured as days after June 1. Two linear regression lines were calculated, one for the period up to 300 days and one for the period after 340 days (a 40-day period around the point of inflection of the disease progress curve was omitted to lessen bias). The two lines intersected at 334 days after June 1, or April 30. This date represents the average beginning of infection period three and is the latest date at which a chemical control program should begin. This conclusion has since been substantiated in field trials (12).

The three possible infection periods and the normal 4-yr life of a needle change the familiar concept of an annual disease cycle into a disease spiral that takes about 28 mo to complete (6). A linear diagram (Fig. 3) best explains these relationships. For example, the newly formed 1975 needles (usually completely elongated about 1 July) were first infected between 15 July and 30 August 1975. The ascospores infecting these needles originated from overwintered apothecia on 1973 needles cast in the fall and winter of 1974–1975. Immature needles apparently are not susceptible; in all our studies, no infection occurred before the needles were fully elongated. Previous studies (8) showed that the needles lying in the duff and bearing the apothecia began to decay by early August. Ascospore release declined rapidly to almost zero, and many released ascospores failed to germinate, essentially terminating infection by the end of August.

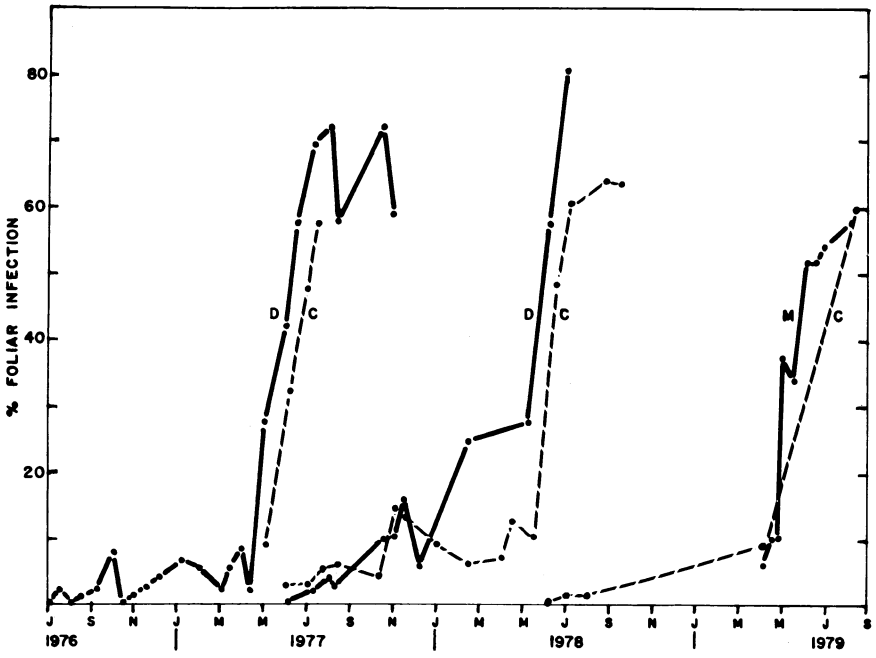

Fig. 1. Disease progress curves for infection of the 1976 and 1977 needles of Scots pine in a Dushore plantation (D); the 1976, 1977, and 1978 needles in a Curwensville plantation (C); and the 1978 needles in a Mingoville plantation (M); all in Pennsylvania.

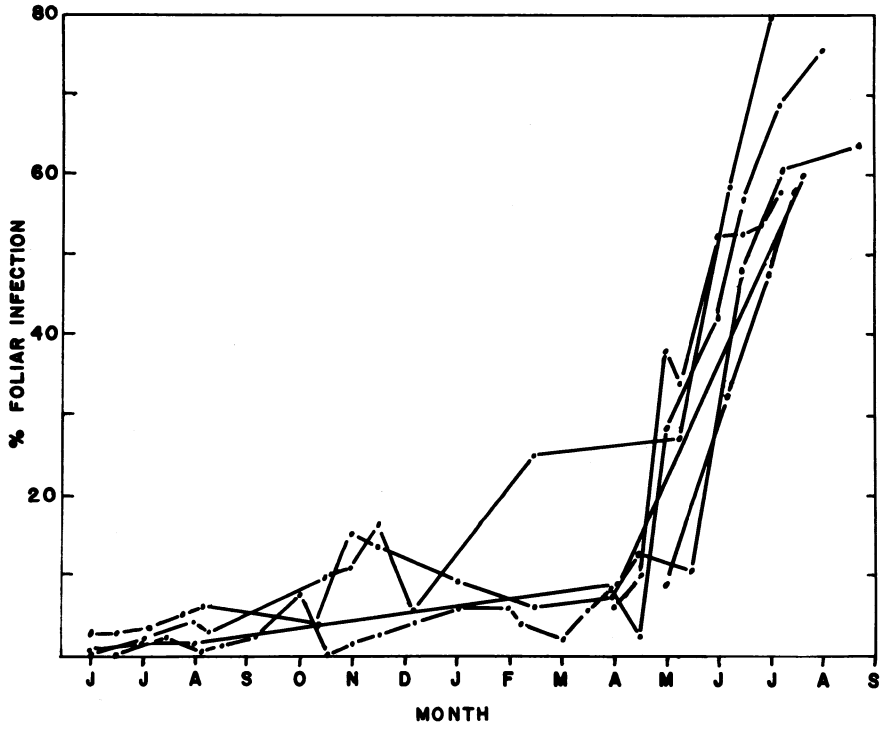

Fig. 2. The six disease progress curves of Fig. 1 plotted on a common time scale.

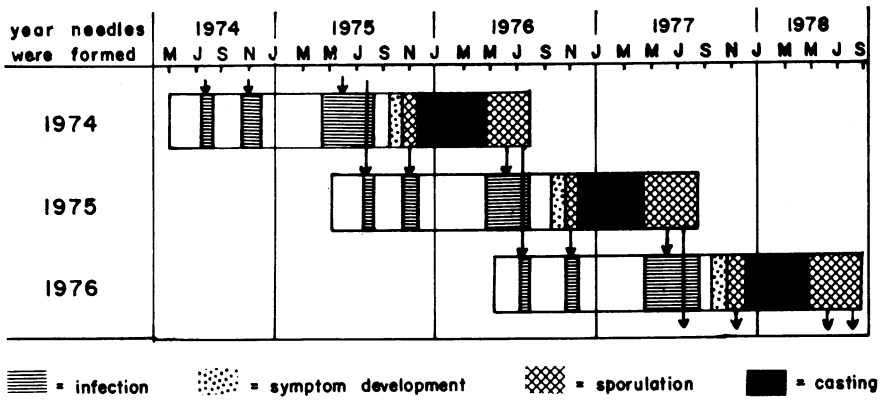

Fig. 3. Diagram of the disease cycle of *Naemacyclus minor* needlecast of Scots pine in Pennsylvania, illustrating the timing of infection, symptom development, sporulation, and casting of infected needles. Each horizontal bar represents the progress of one complement of needles from emergence from the fascicle sheaths until it no longer functions as an inoculum source. Arrows link periods of sporulation on one complement of needles with infection periods on subsequent complements.

Infection again occurred during period two, mainly from early November to mid-December 1975. At that time, freshly formed apothecia on the 1974 needles were releasing ascospores and environmental factors still favored infection. Winter weather conditions terminated possible major infection by mid-December.

About mid-April 1976, weather conditions again favored infection. Infection occurred until late August, when the apothecia began to decay and inoculum levels became very low. The ascospores infecting the needles came from the overwintered apothecia on 1974 needles cast during the fall and winter of 1975–1976. These ascospores also infected the newly formed 1976 needles from mid-July to late August, thus infecting two complements of needles at the same time.

Typical symptom development, sporulation, and casting of the 1975 needles then occurred from mid-September to late December 1976. Depending on when needles are infected, the incubation period of *N. minor* (the period between infection and symptom development) can vary from 2 to 16 mo.

Any combination of the three infection periods may occur in any given year, but in Pennsylvania, period three is most important, period one is of secondary importance, and period two usually is insignificant. Thus if needles escape infection the first growing season, they may become infected the following spring. Infection is not continuous over these time periods; most infection in any given period may occur in 1–2 wk or less.

The multiple infection periods probably explain the failure of chemical control studies conducted by Magnani (9) and G. Peterson (*personal communication*). A fall spray might give some control, but a subsequent spring infection would cause symptom development the following fall.

In summary, needles on susceptible Scots pine are subject to infection by *N. minor* from complete needle elongation until natural needle senescence 4 yr later. Of the three possible infection periods, the spring infection period is most important in Pennsylvania.

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