# DISTRIBUTION AND INFECTION PERIOD OF *PHAEOCRYPTOPUS GAEUMANNII* IN NEW ZEALAND

I. A. HOOD and D. J. KERSHAW
Forest Research Institute, New Zealand Forest Service, Rotorua

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ABSTRACT

Since its discovery in the central North Island of New Zealand in 1959, **Phaeocryptopus gaeumannii** (Rohde) Petrak, a needle parasite of Douglas fir (**Pseudotsuga menziesii** (Mirb.) Franco), has spread over much of the country. It can now be found in most areas where Douglas fir is grown in the North Island and in a number of localities in the South Island, mostly in the northern half. In several North Island areas infected trees are now partly defoliated, but whether **P. gaeumannii** is the prime cause has yet to be determined.

In observations over three years, ascospores were first found within pseudothecia in late August or early September. The percentage of such mature pseudothecia increased to a maximum between September and December but then declined, becoming infrequent during January and February.

Observations on trees and potted seedlings showed that foliage exposed to natural infection for several weeks following flush (late October-November) attained levels of infection exceeding 80%. Infection of foliage exposed after about mid-December to January was reduced to 6% or less. Emergence of pseudothecia was first observed in April and by June they were large enough to be seen with the naked eye.

## INTRODUCTION

*Phaeocryptopus gaeumannii* (Rohde) Petrak is an ascomycetous fungus that parasitises needles of Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco). In most parts of the natural range of Douglas fir in western North America no harmful effects have been noticed as a result of infection (Boyce, 1940; Andrews, 1967). But where Douglas fir has been planted in the eastern half of the United States and in Europe some chlorosis and defoliation associated with *P. gaeumannii* has occurred. These symptoms have been attributed to the infection by *P. gaeumannii* (e.g., Rohde, 1937; Boyce, 1940; Peace, 1962) even though the fungus has not yet been shown to cause the damage.

*P. gaeumannii* was first found in New Zealand at Taupo in 1959, and a country-wide survey indicated that it was then restricted to areas within a 130-km radius of Taupo (Gilmour, 1966). No symptoms of ill health to Douglas fir were reported at that time.

There are over 40 000 ha planted with Douglas fir in New Zealand. Nearly all are south of latitude 37°S, mainly in forests, but also in small woodlots and as isolated trees. This paper records the spread of *P. gaeumannii* within Douglas fir in New Zealand since 1959, and also reports the results of studies into the fungal life-cycle.

## DISTRIBUTION

Periodic forest surveys throughout the country by trained observers, supplemented by laboratory confirmation, have recorded the distribution of the fungus in New Zealand since 1959 (Fig. 1). Between 1960 and 1969 the fungus gradually spread through most

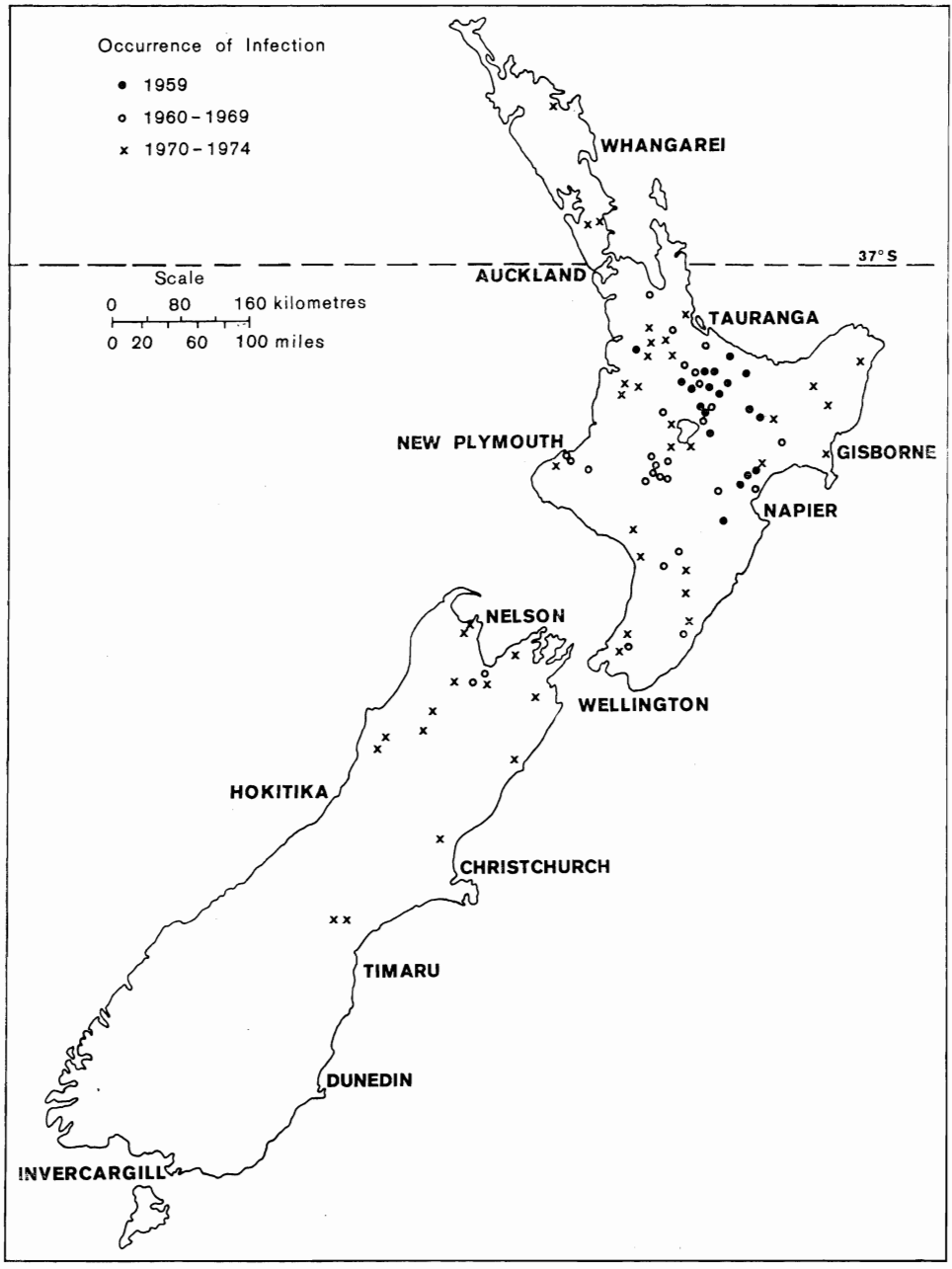


FIG. 1—Distribution of **Phaeocryptopus gaeumannii** on Douglas fir in New Zealand.

of the Douglas fir in the North Island. It was found for the first time in the South Island in 1969 near Nelson. By 1974 the distribution in the North Island was virtually complete, and in the South Island the fungus had spread through Nelson and Marlborough, into northern Westland and to three locations in Canterbury.

From as early as 1962 symptoms of chlorosis and needle loss were noticed in forests of Douglas fir growing in the central North Island (N.Z. Forest Research Institute, unpublished records). Re-measurement of growth and yield plots in Kaingaroa Forest in 1973 indicated that there was a decline in the expected growth increment of 40-50-year-old stands (N.Z. Forest Research Institute, Symposium No. 15, in press).

## LIFE CYCLE

### *Spore Production*

Five heavily infected Douglas fir trees about 10 m tall growing at Rotorua were selected for observation. At intervals between September and February during the 1971-72 growing season two to three one-year-old needles were removed from each tree approximately 2 m above ground level. Pseudothecia were scraped from needles, squashed and stained in lactophenol cotton blue, and examined microscopically for the presence of spores. Counts were made of 50-100 pseudothecia per tree during each examination and the percentage of pseudothecia containing ascospores was determined. From August to October, 1972, this procedure was repeated with four other trees 6-10 m tall, when counts were made of 100-200 pseudothecia per tree. It was not possible to continue the counts into 1973. The same technique was used once more in the 1973-74 season using one tree 5 m tall. During this third period pseudothecia from two-year-old needles were also considered and 150-200 fruiting bodies from each needle age-class were counted during each examination. The ability of ascospores to germinate was also tested during the 1970-71 season.

In the 1971-72 season ascospores were first seen early in September and spore-bearing pseudothecia were most abundant on one-year-old foliage during late September-November (Fig. 2). The percentage of pseudothecia containing ascospores then gradually declined and ascospores became infrequent during January and February. Results from the other two seasons and from pseudothecial counts on two-year-old foliage showed a similar seasonal trend. Viable ascospores were present at least as early as 15 September, before Douglas fir had flushed, and as late as 13 January.

### *Infection Period*

During the 1969-70 season twelve shoots were selected on each of two open-grown trees about 10 m tall. These shoots were situated in the lower half of the crown 1-5 m above ground level. Immediately prior to flush buds were enclosed in transparent spore-proof bags made from cellulose sausage-casing material permeable to water-vapour and measuring approximately 20 cm × 12 cm. Between October and May at recorded intervals individual bags were removed exposing newly-flushed foliage to natural infection. In August 1970, when the pseudothecia on current foliage could be clearly seen with a hand lens, the percentage of needles infected on each shoot was determined by counting a sample of needles. The experiment was repeated during the 1970-71 and 1971-72 seasons with several slight modifications. In 1970-71 three trees were used and on one of these individual bags were replaced onto shoots after the new foliage had been exposed to infection for periods of 1-3 weeks. All bags on this tree were

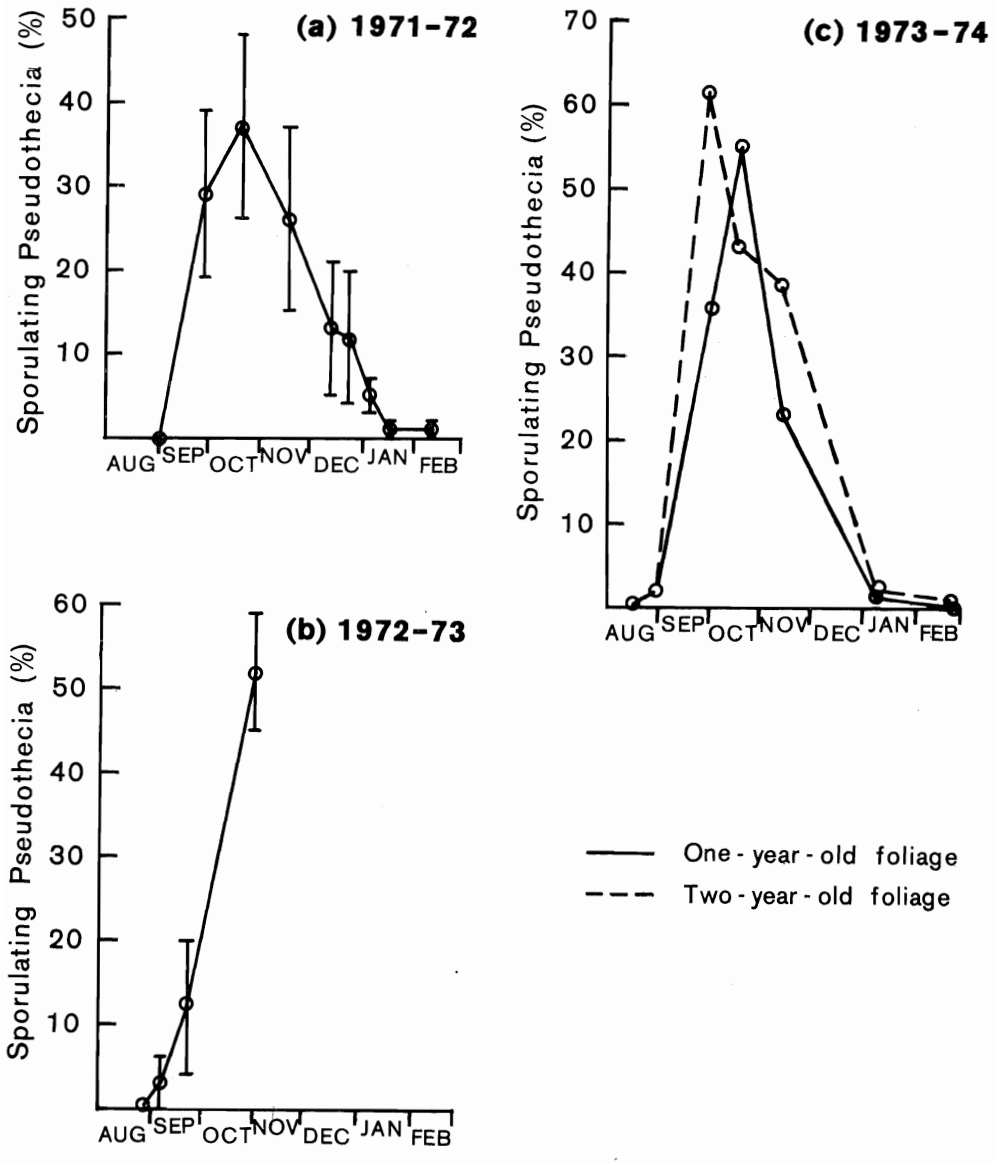


FIG. 2—Seasonal abundance of pseudothecia containing ascospores. Bars indicate standard deviations about mean values in years when more than one tree was used.

then finally removed in March. In 1971-72 only one tree was used and shoots on this tree were re-enclosed after being exposed for periods of 1-2 weeks. All bags were again finally removed in March. Over the three seasons the numbers of needles counted per shoot ranged from 70 to 600.

An experiment was also carried out with potted seedlings. During the 1971-72 season small groups of uninfected two-year-old seedlings were placed outside on the ground beneath a heavily infected tree for periods of 7-18 days before returning to

glasshouse cover. Seedlings were only placed outside if they bore newly-flushed foliage, still soft and tender but with needles well extended. Cold treatment was used to delay the flush of some plants to ensure a supply of seedlings with needles still fresh even in January and February, when such foliage has normally begun to harden. Seedlings were assessed for percentage needle infection in August 1972.

The results of infection period experiments using shoots on trees are displayed in Fig. 3. New foliage exposed during November and early December became well infected,

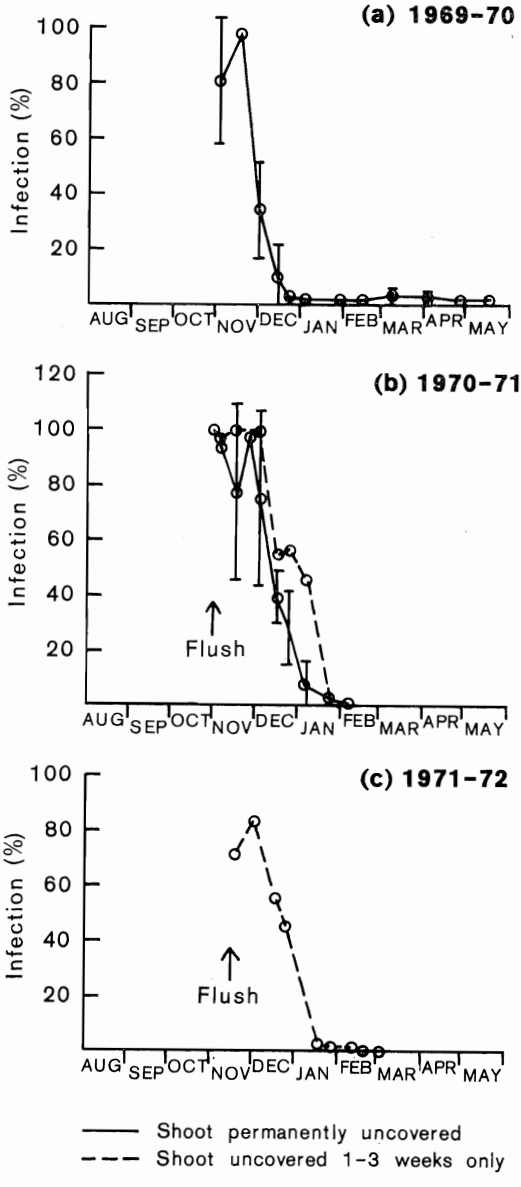


FIG. 3—Infection period using shoots on trees. Bars indicate standard deviations about mean values in years when more than one tree was used.

but thereafter infection levels decreased to 6% or less. The date beyond which infection levels were always low (less than 6%) varied in different years between mid-December and late January. During the 1970-71 season replacement of bags onto shoots 1-3 weeks after exposure to natural inoculum instead of leaving shoots exposed for the remainder of the season appeared to have no effect on the infection levels of foliage.

Results obtained from the seedling experiment were more irregular and infection levels were lower. No seedlings exposed after the beginning of January had more than 2% of their current foliage infected.

*Infection of Foliage during Subsequent Seasons*

As a result of the 1969-70 work using shoots on trees to determine the infection period, a number of shoots were obtained with inoculum levels of only 6% or less (Fig. 3 (a), January-May). It was observed in the following year that a number of these shoots on one tree showed increases in infection at levels ranging from 2% to 41% per shoot after having been exposed to natural inoculum for the whole of their second season. On the other tree, however, no increases in infection during the second year of needle life occurred after a similar exposure of shoots to natural inoculum. This suggested that at least on some trees one-year-old foliage can become moderately infected. In September 1972, immediately prior to flush, ten uninfected three-year-old Douglas fir potted seedlings grown under glasshouse cover were placed for six months beneath a heavily infected stand of 13-year-old Douglas fir. Seedlings were assessed for infection in October 1973. A total of 100 needles of each age class were examined per seedling. Some casting of two-year-old needles of all seedlings had occurred at the time of assessment.

Results are shown in Table 1. Foliage that was one year old at the time that it was exposed to natural inoculum became infected at levels ranging from 1%-39% on different seedlings. By contrast, new foliage became 98%-100%infected.

TABLE 1—Infection after exposure of uninfected seedlings to natural inoculum for one season

| Seedling | Percentage needles infected | |
|---|---|---|
| | New-flushed foliage* | One-year-old needles* |
| 1 | 100 | 8 |
| 2 | 100 | 19 |
| 3 | 100 | 4 |
| 4 | 100 | 19 |
| 5 | 100 | 39 |
| 6 | 100 | 1 |
| 7 | 98 | 1 |
| 8 | 100 | 5 |
| 9 | 100 | 14 |
| 10 | 100 | 7 |
| Mean | 99.8 | 11.7 |
| Stand Dev. | 0.6 | 11.7 |

* At time of infection.

*Development of Fruiting Bodies*

Transmitted- and incident-light microscopy were used to follow the development of pseudothecia from first appearance to maturity during 1971 on foliage of trees in Rotorua.

In March 1971 newly-formed pseudothecial initials could be seen within the stomata of 4-5-month-old needles by using transmitted light. First external signs of pseudothecia were observed during April as they enlarged, forcing out the stomatal wax plugs. By May pseudothecia on many current needles could be detected with a hand lens and in June they could just be seen on some with the naked eye. Pseudothecia continued to enlarge reaching maturity in September.

## DISCUSSION

The infection pattern, determined by successively uncovering shoots on trees, parallelled the seasonal trend in abundance of ascospore-bearing pseudothecia. The decline in infection during January and February may therefore simply be due to the reduction in the number of spores available at this time. It does not appear to be attributable to a loss of spore viability, since viable spores were found at least as late as mid-January. Nor does the decline in infection levels during January and February appear to be directly attributable to the hardening and maturing of the new foliage that takes place at this time. In the experiment to determine the infection period using seedlings, shoots were cold-treated in order to delay bud-burst artificially so that new foliage was still fresh and tender in January and February when exposed to natural inoculum. Despite this treatment the new foliage still failed to become infected. Other factors contributing to this reduction of infection cannot be ruled out, however. For instance, the weather conditions prevailing during January and February could affect spore release, spore germination, or germ tube development.

Rohde (1937) inferred that needles of Douglas fir, one year old or older, could still become infected to some degree by *P. gaeumannii* and that resistance to infection was only established after several years. Although Merkle (1950) claimed to have shown that older needles could be freshly infected, Peace (1962) believed that infection occurred over a relatively short period, when needles were not fully hardened. The results reported here support the claim of Merkle but also imply that a high level of infection does not occur after the first year of needle life.

A number of authors have reported their observations of the life cycle of *P. gaeumannii* in plantations of Douglas fir both in Europe (e.g., Rohde, 1937; Merkle, 1950; Krampe & Rehm, 1952) and in the eastern half of the United States (Boyce, 1940; Morton and Patton, 1970; Ford and Morton, 1971; Chen, 1972). These authors found that ascospore production coincided with bud-burst and new shoot growth of Douglas fir during the Northern Hemisphere late spring and early summer. The work reported here shows that *P. gaeumannii* behaves in a similar manner in New Zealand.

It is important to know the period when infection occurs if *P. gaeumannii* is to be controlled with fungicides. This work has indicated that foliage must be protected from infection from the time of flush, in October or November, up to late January.

ACKNOWLEDGMENTS

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