Infection, Epidemiology, and Control of Diplodia Blight of Austrian, Ponderosa, and Scots Pines

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ABSTRACT

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Infection of vegetative shoots of Austrian, ponderosa, and Scots pines by *Diplodia pinea* preceded infection of pollen cones. Pollen cones were seldom infected. Second-year seed cones of the three pine species became infected as early as late May; first-year seed cones were not infected. Infected seed cones were commonly observed on trees with noninfected shoots. Pycnidia developed extensively on second-year seed cones and needles in the autumn of the year of infection if late summer rain was plentiful, but not until spring if rainfall was below normal. *Diplodia pinea* on Austrian pines in eastern Nebraska was controlled by two applications of Bordeaux mixture applied within a 2-wk period (about 24 April - 8 May) beginning with bud expansion; later applications were ineffective. The early applications of fungicide to control shoot infection did not prevent infection of second-year seed cones.

Additional key words: *Pinus nigra*, *P. ponderosa*, *P. sylvestris*.

Damage to pines by *Diplodia pinea* (Desm.) Kickx is increasing in the Great Plains, particularly in plantings over 30 years old (4). The biological information needed for effective and economic control is incomplete. Brookhouser and Peterson (2), through inoculation and observation of 10-yr-old pines (*Pinus nigra* Arnold, *P. ponderosa* Laws., *P. sylvestris* L.), found that new shoots were susceptible to infection from late April to late June in eastern Nebraska. Since then, experiments have been conducted at the Forestry Sciences Laboratory in Lincoln to determine the number and timing of fungicide applications needed for effective control. Furthermore, since abundant inoculum is produced on seed cones, investigations have been made to determine when seed cones are susceptible, and whether fungicide applied at times necessary to control infection on shoots also would reduce infection of seed cones. Since pollen cones develop during the period of high susceptibility, investigations were made to determine if pollen cones are susceptible, and whether there is a relationship between infection of vegetative shoots and pollen cones. A partial account of this work has been reported (3).

MATERIALS AND METHODS

Infection of new shoots.—Infection was evaluated in Austrian pines (*P. nigra* Arnold) in a 1934 planting in Pioneers Park, Lincoln, Nebraska in 1971, 1972, and 1973. Trees were sprayed with Bordeaux mixture (8-8-100) with varying frequency and on different dates. Fungicide was applied at 32 kg/cm^2 to point of run-off; approximately 35 liters of spray were used per tree. Treatments were randomly assigned to trees; four trees were used per treatment. All new shoots on each of four major branches which had been selected prior to treatment were examined twice (mid-June and mid-July) to determine the percentage of shoots infected. Results were analyzed statistically, using Duncan's multiple range test. Lengths of new shoots and needles were measured weekly on each test tree so that stage of growth could be related to dates fungicide was applied. Weather data were obtained from a weather station 8 km from the test area.

Infection of seed cones.—First-year (current-year) and second-year seed cones from Austrian, Scots, and ponderosa pines were collected at approximately 2-wk intervals from 17 May to 19 November 1971. Ten cones of each age class from each species were collected from trees that had been heavily infected. In 1972, second-year cones of the three species were collected weekly from 5 April to 27 June. Cones were examined for pycnidia of *Diplodia pinea* before and after they were placed under conditions (24 C and 100% relative humidity for 5 days) which enhanced development of pycnidia. Isolations were attempted from cones on which no pycnidia were observed; cone tissues (scales, peduncle, and axis) were plated on PDA to determine if *D. pinea* was present.

Lengths and widths of second-year seed cones were measured weekly from late April to early June in 1972 and 1973. Nine cones (three from each of three trees) of the three species were measured repeatedly.

Infection of pollen cones.—Pollen cones were collected weekly from the three pine species during the period 5 April - 12 June 1972. Pollen cone tissue was plated on PDA to see if *D. pinea* was present. The pollen cones were incubated (24 C, 100% relative humidity) for 5 days to see if pycnidia of *D. pinea* would develop. The extent of cone development was noted also. In 1973, pollen cone lengths were measured weekly during the period 17 April - 22 May on cones from the same three shoots on each of three trees of each of the three pine species.

RESULTS

Infection of shoots.—Occurrence of resin droplets on shoots was the first obvious indication of infection. These droplets were observed as early as the first week in May. Commonly, one or a few necrotic (brown) needles were observed near the droplets; these needles were much shorter than non-necrotic needles. These needles became necrotic while still encased in fascicle sheaths. Necrosis developed rapidly in infected shoots; these shoots turned yellow to tan. All needles of a shoot often became necrotic before any of them had emerged from fascicle sheaths. On some infected shoots, most of the needles emerged from sheaths before extensive necrosis developed, but these needles usually were much shorter than needles on noninfected shoots.

Numbers of infected shoots in mid-July were only slightly higher than in mid-June; thus, only the July data are presented.

Infection levels were high in 1971 and 1973 and moderate in 1972 (Table 1). In all 3 yr, rain fell during each interval between spray dates; thus, spore dispersal and infection were possible in each interval. Percentage infection in 1971 of shoots sprayed for the first time on 13 May was nearly double the percentage infection of shoots sprayed for the first time on 29 April. This indicated that the period of high susceptibility was prior to mid-May. Accordingly, in 1972 and 1973 fungicide was applied prior to mid-May. A single application on 17 April 1972 resulted in low infection, but in 1973 infection was high on shoots receiving a single application on 17 April. In both 1972 and 1973, two applications on 24 April and 1 May, or 1 May and 8 May were very effective. Single applications on 24 April in 1972, and 1 May, or 8 May in 1972 and 1973 were less effective than two sprays at weekly intervals. Thus, 24 April to 8 May is the period of high susceptibility of shoots. This period is characterized by opening of buds and partial elongation of shoots. It occurs before needles have emerged from fascicle sheaths and before rapid elongation of shoots ceases (Fig. 1).

Infection of seed cones.—No first-year (current-year) seed cones of Austrian, ponderosa, or Scots pines collected periodically during the growing season were infected. *Diplodia pinea* was not isolated from these cones, nor were pycnidia found on them before or after incubation.

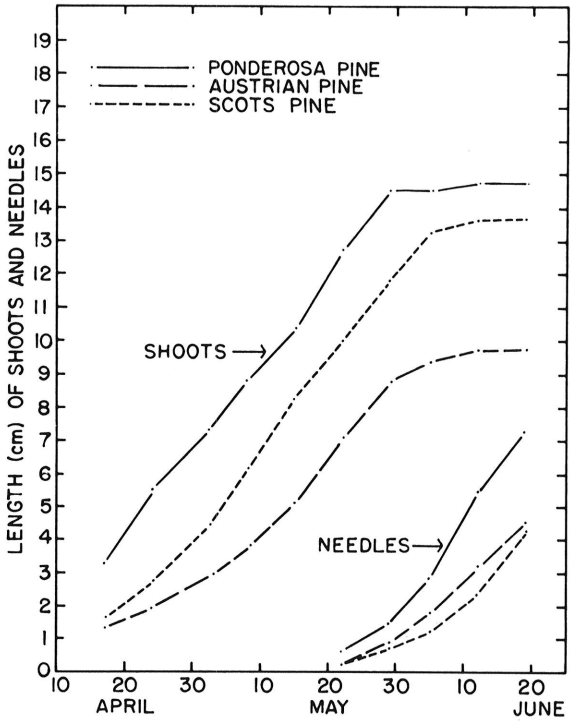

Fig. 1. Seasonal elongation of shoots and needles of Austrian, ponderosa, and Scots pines.

TABLE 1. Infection by *Diplodia pinea* of Austrian pines treated with Bordeaux mixture at various times in Lincoln, Nebraska

	Infection[a,b] (%)		
Dates fungicide applied	1971	1972	1973
17 Apr 1972, 1973		2.6 A	27.9 CD
17 and 24 Apr 1973			14.3 ABC
24 Apr 1973			11.4 ABC
24 Apr and 1 May 1972, 1973		3.9 A	5.5 AB
29 Apr 1971	24.9 A		
29 Apr and 27 May 1971	25.9 A		
1 May 1972, 1973		11.9 AB	18.9 BC
1 and 8 May 1972, 1973		3.7 A	2.0 A
1, 8, and 15 May 1972		7.2 A	
8 May 1972, 1973		9.0 A	29.8 CD
8 and 15 May 1973			23.5 BC
13 May 1971	54.1 B		
13 and 27 May 1971	51.9 B		
13 and 27 May and 10 June 1971	43.5 B		
Check (not treated)	56.5 B	24.1 B	47.4 D

[a]Each figure represents the percentage of infected shoots on each of four major branches on each of four trees.
[b]Unlike letters denote significant difference, $P = 0.05$, according to Duncan's multiple range test.

Second-year cones of the three species became infected early in the growing season. Austrian pine cones collected 17 May 1971 were not infected; but cones collected 10 days later were, as determined by isolations and development of pycnidia in dew chambers. In 1972, second-year cones of the three species collected 22 May were not infected, but cones collected 8 days later were. Seed cones became infected when they were rapidly expanding (Fig. 2).

The extent of pycnidial development on second-year seed cones varied considerably depending on the year they became infected. On 1970 seed cones of Austrian pine infected in 1971, pycnidia first were observed on a few cones 8 August 1971. By 5 April 1972, pycnidia still were not evident on most cones; it was not until 30 May 1972 that pycnidia were numerous on many cones. In contrast, 1971 seed cones infected in 1972 had numerous pycnidia by 7 September 1972. This more rapid development was probably related to high moisture (166 mm) in late summer and early fall of 1972; moisture was very low (48 mm) during the comparable period in 1971.

Infected seed cones of all three species were found on trees whose shoots were not infected. Observations revealed that previously noninfected trees are more likely to become infected on seed cones than on new shoots.

Infection of pollen cones.—Pollen cones began expanding rapidly early in the period of high susceptibility of Austrian pine shoots (24 April- 8 May). There was no indication, however, that the fungus first infected pollen cones, then grew into vegetative shoots. *Diplodia pinea* was isolated only three times from pollen cones, and then only from late collections, suggesting that the fungus may have entered the cones via infected vegetative shoots. Pycnidia did not develop on incubated pollen cones from any of the collection dates, except on a few cones collected 19 June from infected shoots.

DISCUSSION

This investigation established that Diplodia blight on Austrian pines can be effectively controlled by two closely spaced applications of Bordeaux mixture. Previously it had been shown that infection of shoots can occur over a rather long period – from budbreak to late June in eastern Nebraska (2) —but these results show that shoots are highly susceptible for a much shorter period (24 April - 8 May). Arborists who have used spray schedules developed from this research obtained excellent control of Diplodia blight in 1974 and 1975 in Lincoln, Nebraska.

Because the chronology of growth and development of shoots of ponderosa and Scots pines is similar to those of Austrian pine, tip blight on all three pines probably can be controlled by the same schedule of fungicide applications.

Bordeaux mixture was used in this study primarily because it is effective against Dothistroma needle blight of pines, which is also a problem in the Great Plains.

Shoots are highly susceptible to Diplodia blight before second-year seed cones become susceptible and before the rapid enlargement of second-year seed cones. This is in accord with the observation that fungicide applications that are effective in preventing shoot infection were ineffective in preventing infection of second-year seed cones. Thus, a program to reduce the amount of inoculum by reducing infection of second-year seed cones would require that fungicide also be applied after the period of high susceptibility of shoots.

Initial infection of previously noninfected trees of all three pines on second-year seed cones and not on shoots suggests that seed cones are either more susceptible, or that they are susceptible for a longer period, than are the shoots. Incidence of shoot infection is usually much higher on trees in older plantings than in young plantings, probably because older trees produce more seed cones on which inoculum can be produced in abundance.

Though infection has been most severe in the eastern Great Plains on trees over 30 yr old, younger trees are susceptible. Slagg and Wright (6) reported that pine seedlings in nursery beds were infected by *D. pinea*. I have observed infected pine seedlings as well as infected 10- to 12-year-old pines also, but in each instance there were old pines nearby whose cones contained great numbers of *D. pinea* pycnidia.

Infection of *Pinus radiata* D. Don in Australia often has followed wounding by hail (5). This has led some investigators to report that *D. pinea* is strictly a wound parasite and that infection of previously healthy tissue does not occur (1, 5). The results of this investigation, in which up to 100% of the newly developed shoots became infected, disprove that theory.

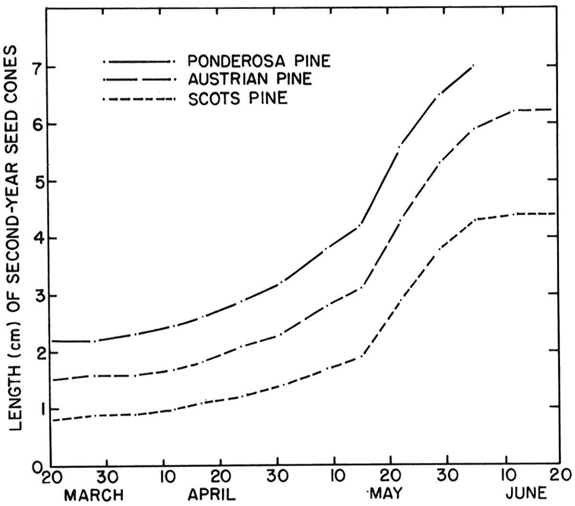

Fig. 2. Seasonal elongation of second-year seed cones on Austrian, ponderosa, and Scots pines.

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