Leptographium terebrantis and Black Turpentine Beetles Associated with Blue Stain and Mortality of Black and Scots Pines on Cape Cod, Massachusetts

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ABSTRACT

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Mortality of Japanese black (*Pinus thunbergiana*) and Scots (*P. sylvestris*) pines on Cape Cod, Massachusetts, followed attack by the black turpentine beetle (*Dendroctonus terebrans*) and the staining fungus *Leptographium terebrantis*. Blue stain caused by *L. terebrantis* developed beneath larval galleries of the beetle in the lower bole and buttress roots and was followed by foliar symptoms and attack by bark beetles (*Ips* sp.) and other staining fungi.

Unnatural rates of mortality of Japanese black pine (*Pinus thunbergiana* Franco) and Scots pine (*P. sylvestris* L.) have occurred during the past 20 yr on Cape Cod, Massachusetts. Becker (2) attributed the death of these trees to the girdling effect of the black turpentine beetle (*Dendroctonus terebrans* (Oliv.)) (Coleoptera: Scolytidae). However, a blue stain fungus (*Leptographium* sp.) was found consistently growing in the sapwood of symptomatic trees (10). Blue stain fungi-bark beetle associations have caused extensive losses in pines elsewhere throughout the United States (3–6,9). The black turpentine beetle kills pines predominately in the southeastern United States and on Cape Cod in the northernmost part of its range (2). The objective of this study was to better understand the role of *Leptographium*-bark beetle associations in the death of Japanese black pine and Scots pine on Cape Cod.

MATERIALS AND METHODS

Field plots were located in Falmouth, Cape Cod, MA, in areas of expanding black turpentine beetle infestations. Japanese black pines in an ornamental planting 15–25 yr old were located in an approximately 1-ha plot, and Scots pines 50–60 yr old were located in a 3-ha forest plot. All trees within the plots were observed biweekly from April (onset of shoot elongation) through October during 1981 and 1982.

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The trees in each plot were divided into the following foliar symptom categories: green, green/chlorotic, chlorotic/brown, and brown. Six Japanese black pines and at least three Scots pines in each category were felled, and cross sections 5 cm thick were cut through the stems at 3-cm intervals from the base toward the crown until blue stain discoloration ended (3). Sections were returned to the laboratory and examined immediately or stored at 5 C for later examination. Patterns of discoloration in the xylem of each section were recorded by tracing onto clear acetate films. Tree age and growth rate were determined from growth rings.

The bark was removed from each section, and any beetle galleries and/or blue stain discoloration in the outer sapwood were examined. The widths of all beetle galleries in the cambial zone were also measured.

For microbial isolation, disks were split radially and sections (3 × 10 mm) of discolored and nondiscolored wood were removed from the exposed surface with a sterile wood gouge. Sections were placed on 2% malt agar and incubated at room temperature.

RESULTS

Symptom progression. The radial growth rates of the Japanese black pines ranged from 2 to 5 mm per year. The growth rates of Scots pines from 1962 to 1982 ranged from 0.8 to 1.25 mm per year. Foliar symptoms in Japanese black pine always followed attack by the black turpentine beetle. Healthy, green trees turned completely brown within 2–3 mo. Needles throughout the entire crown first turned green/chlorotic, then chlorotic/brown and brown in rapid succession. This symptom progression occurred from April to December. All symptomatic Scots pine trees also had been attacked by the black turpentine beetle. The foliage of unattacked trees was sparse and the crowns appeared thin. After trees were attacked by the black turpentine beetle, the green/chlorotic stage occurred in a few branch tips and then spead throughout the crown. The entire crown turned chlorotic/brown, followed by complete browning that began in scattered branch tips and gradually spread through the crown. The progression of symptoms in Scots pine was not as rapid as in Japanese black pine. Some trees turned brown within a few months, but most took a year from onset of symptoms.

Bark beetle activity. Japanese black pines with relatively few pitch tubes (<10/tree) on the lower bole showed foliar symptoms. Black turpentine beetle attacks were found on the buttress roots above ground. On symptomatic trees with no visible pitch tubes above ground, beetle attacks were found below ground. Scots pines showing foliar symptoms were attacked more heavily (>25 pitch tubes per tree) by the black turpentine beetle on the lower bole. Attacks were also observed below ground on the buttress roots, most frequently on trees with heavy attacks of the lower bole. Mining activity by the black turpentine beetle increased dramatically during symptom progression in both Japanese black and Scots pines. Light brown frass associated with black turpentine beetles was also seen around the bases of attacked trees of both species.

Ips pini (Say) (Coleoptera: Scolytidae) were also observed in increasing numbers on both species of trees in the chlorotic/brown and brown symptom categories. Mining by *Ips*, however, did not occur in the green symptom category of either pine species and was also absent in the green/chlorotic category of Japanese black pines. Mining by *Ips* increased progressively in both tree species in the more severe symptom categories.

Patterns of blue stain discoloration. Blue stain in cross sections of Japanese black pines was typically wedge-shaped (Fig. 1). Blue-stained sectors extended radially from the cambium and were associated with areas of attack by black turpentine beetles. Cross sections also showed resin-soaked xylem in wedges associated with black turpentine beetle galleries. The living bark and sapwood of Japanese black pines appeared wet when felled, and a copious amount of resin exuded from cut surfaces.

Patterns of discoloration in Scots pines

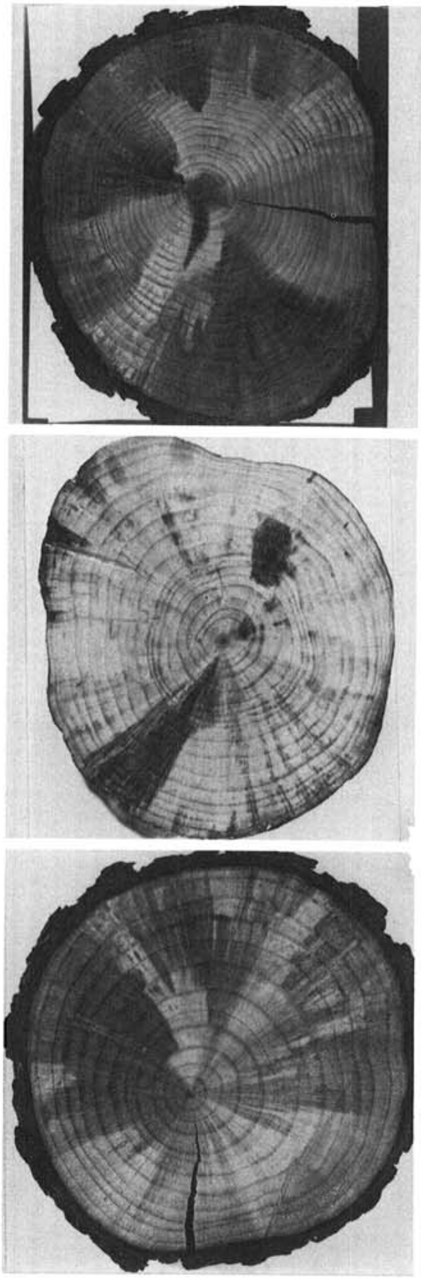

Fig. 1. Cross-sectional views of blue stain patterns associated with black turpentine beetle activity in the lower boles of Japanese black pines in chlorotic/brown or brown foliar symptom category.

differed from those in Japanese black pines. Scots pines had a clearly defined heartwood in contrast to Japanese black pines, which did not. The blue stain in the lower bole (<2 m above ground) of Scots pines did not appear as isolated wedges in the sapwood but rather as a discontinous band (Fig. 2). The discoloration in the upper bole (>4 m above ground) appeared as distinct, narrow wedges associated with galleries of *Ips* beetles (Fig. 3). Resin-soaked wood was not observed in cross sections of beetle-attacked Scots pines. The wood appeared dry when trees were felled, and very little resin exuded from the cut surfaces.

Fig. 2. Cross-sectional view of blue stain patterns associated with black turpentine beetle activity in lower bole of a Scots pine in the chlorotic/brown or brown symptom category.

The lengths of discolored sectors and the percentage of circumference with blue stain increased as the crown declined in both Scots and Japanese black pines (Table 1). Trees attacked by the black turpentine beetle and displaying green crowns had no blue stain, whereas trees in the brown crown condition had the highest amounts of blue-stained sapwood. The total amount of blue-stained xylem was greater in Scots pines than in Japanese black pines. The vertical extent of the blue stain discoloration was slightly greater than that of the area of black turpentine beetle attack. The height of discoloration increased as the crown condition declined. Scots pines consistently had longer columns of discoloration above ground than did Japanese black pines.

Isolations from wood. *Leptographium terebrantis* Barras & Perry was isolated consistently from blue-stained sections of

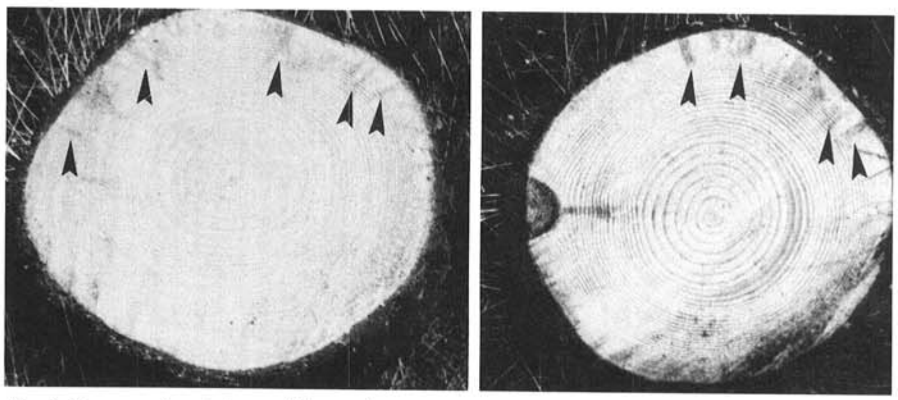

Fig. 3. Cross-sectional views of blue stain patterns associated with *Ips* beetle activity (arrows) in upper boles of Scots pines in the chlorotic/brown or brown symptom category.

Table 1. Relationship between foliar symptoms, blue stain of xylem, and insect mining in Japanese black and Scots pines

		Blue stain of xylem		Beetle mining		
				Dendroctonus terebrans		*Ips*
Species	Foliar category	Length (m)	Circumference (%)	Circumference (%)	Length (m)	Circumference (%)
Japanese black pine[a]	Green	0	0	20.7 (10.9)	0.43 (0.17)	0
	Green/chlorotic	0.22 (0.12)	12.8 (18.5)	42.8 (27.0)	0.32 (0.14)	0
	Chlorotic/brown	0.50 (0.31)	32.8 (19.2)	50.2 (28.8)	0.32 (0.06)	43.5 (6.6)
	Brown	1.31 (0.46)	63.5 (15.8)	86.7 (23.1)	1.01 (0.37)	63.3 (47.3)
Scots pine[b]	Green	0	0	17.1 (2.6)	0.9	0
	Green/chlorotic	1.0 (0.17)	32.9 (0.1)	87.5 (17.6)	1.0 (0.17)	30.0 (42.4)
	Chlorotic/brown	2.23 (0.76)	80.3 (3.15)	90.7 (16.2)	1.1 (0.17)	71.3 (11.0)
	Brown	8.53 (1.36)	84.0 (23.7)	89.5 (14.8)	0.9 (0.19)	85.0 (7.1)

[a] Means of six trees per category; standard deviation in parentheses.
[b] Means of at least three trees per category; standard deviation in parentheses.

sapwood in the lower bole. An unidentified nonsporulating fungus was also obtained from blue-stained wood around *Ips* galleries. White aerial mycelium covered the surface of the culture plate, and the underside of the colony was blue-black.

DISCUSSION

Barras and Perry (1) found *L. terebrantis* associated with *D. terebrans* in loblolly pine. The association of black turpentine beetle with *L. terebrantis* in pines on Cape Cod causes different symptoms in Japanese black pine than in Scots pine. The Scots pines were already in a state of decline as seen by their sparse crowns and slow growth rates. After attack by the black turpentine beetle, the trees declined more rapidly and were heavily colonized by blue-stained fungi and *I. pini*. The Japanese black pines were younger trees with full crowns and were growing at a normal rate. These trees, although they did not appear stressed, were attractive to the black turpentine beetle. The trees died within 2–3 mo of oviposition, and when viewed in cross section, showed resin wedges beneath the galleries. These resin-soaked areas, in addition to nonfunctional blue-stained wood, could account for their rapid death.

The blue-stained patterns observed in both species were related to the amount of beetle activity. Small numbers of galleries resulted in discrete wedges in the xylem, and large numbers of galleries resulted in coalescing sectors of stained wood and eventually a continuous band of stained outer sapwood. These patterns were also related to the amount of time following attack, as observed by others (7). In Scots pines, uninterrupted vertical sectors of blue stain occurred in trees with brown crowns; trees in earlier stages of decline had broken columns.

The different patterns of discoloration in sapwood can be related to the species of bark beetle, its gallery characteristics, and the direction of fungal growth in the wood (8). Larvae of *D. terebrans* mine gregariously in the lower bole, inoculating a large surface of the sapwood, resulting in wide blue-stained wedges as the fungus grows inward along the rays. *Ips* larvae in the upper bole mine individually, inoculating a smaller surface area, resulting in narrow blue-stained wedges in the xylem. Since the fungi invade living xylem primarily along the rays, the type of gallery probably accounts for the patterns of xylem discoloration observed.

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