L. David Dwinell, Jane B. Barrows-Broaddus, and E. George Kuhlman
USDA Forest Service Southeastern Forest Experiment Station, Athens, GA

Pitch Canker: A Disease Comple

A disease complex caused by *Fusarium moniliforme* Sheld. var. *subglutinans* Wollenw. & Reink. (FMS) is damaging pine plantations and seed orchards in the southeastern United States. Over 45% of the nation's pulpwood is grown there, and this percentage is expected to increase. This area practices the most intensive forestry in the country; site preparation, planting, and short rotations are common, especially in industrial forests. Almost one-half of the slash pine (*Pinus elliottii* Engelm. var. *elliottii*) and one-fourth of the loblolly pine (*P. taeda* L.) inventory are currently in plantations. At least 65% of the 915 million seedlings produced annually are from genetically improved pines grown on 9,800 acres of seed orchards.

We call pitch canker a disease complex rather than a discrete canker disease because FMS infects a variety of vegetative and reproductive plant structures at different stages of maturity and produces a diversity of symptoms. Further compounding the complex is the involvement of several insects, the interaction with other pine diseases, and the marked influence of biotic and abiotic factors on the incidence and severity of the disease. Pitch canker is considered to be endemic to the southeastern United States, and epidemics may be a consequence of intensive forest management practices.

The Disease

Symptoms. Two primary symptoms are associated with pitch canker on vegetative structures of the tree. The classic symptom is a bleeding, resinous canker on the trunk, terminals, or large branches (18) (Fig. 1A). The canker is usually sunken and the bark is retained, while the wood beneath the canker is deeply pitch-soaked (Fig. 1B,C). Pitch-soaking of the underlying wood and the absence of swelling or callus help separate pitch canker from other canker diseases of pines.

The symptom in upper crowns is shoot dieback (Fig. 2) resulting from cankers forming on the late-summer flushes of growth. In autumn, fully developed needles turn yellow to reddish brown. These "flags" continue to appear during winter through spring. Spread of the cankers down the lateral shoots is usually arrested at nodes. In the spring, new shoots may be fully expanded before being killed by girdling of the older tissue. Dead shoots may remain in the crown for several years. Needles that remain on the dead shoots eventually turn gray to grayish brown. Witches' brooms develop in some trees when adventitious buds form in response to repeated infection and dieback (14,15).

Either type of symptom may occur on several pine species. Stem and branch cankers appear on slash, South Florida slash (*P. elliottii* Engelm. var. *densa* Little & Dorman), longleaf (*P. palustris* Mill.), Virginia (*P. virginiana* Mill.), shortleaf (*P. echinata* Mill.), and eastern white (*P. strobus* L.) pines. Infrequent stem cankers on loblolly pine contain only narrow wedges of pitch-soaked tissue (11,17). Shoot dieback occurs primarily on planted slash and sand (*P. clausa* (Chapm.) Vasey) pines in Florida and on loblolly pine in seed orchards throughout the Southeast.

Pitch canker is a problem in tree nurseries. Diseased slash pine seedlings show chlorotic or reddish brown needles and wilting. Pitch-soaked lesions usually occur at or near the soil line but occasionally are found in the region of the cotyledonary node (1). FMS has also been associated with tip dieback of both slash and loblolly pine seedlings. Dead stems turn purple, but the pitch-soaked lesions normally associated with pitch canker on older trees are absent.

FMS also causes mortality of female flowers and mature cones and deterioration of seeds in slash pine (22). FMS-infected loblolly pine cones tend to be misshapen and smaller than normal (Fig. 3), and scales on green cones at harvest time have a purple discoloration. FMS mycelium is often present on outer surfaces of badly deteriorated loblolly cones. Some infected cones have a

Fig. 1. (A) Pitch canker on main stem of eastern white pine showing heavy flow of resin. (B) Pitch canker on shoot of slash pine with bark removed to show resin-soaked wood. (C) Cross section through pitch canker on slash pine trunk showing both resin-soaked (diseased) and healthy wood.

f Southern Pines

necrotic tip characterized by internal pitch pockets. On a few cones from which FMS was isolated we observed resinous lesions (Barrows-Broaddus, *unpublished*). Radiography and isolation (8) have demonstrated the presence of FMS in pine seeds.

Epidemiology. From 1945 to 1973, limited outbreaks of pitch canker were noted in slash, South Florida slash, and Virginia pine stands, but the disease was not considered economically important. Because the production of pitch is so copious following infection in some pine species, attempts were made from 1947 to 1954 to commercially use FMS to stimulate gum flow for naval stores production. However, gum yields following inoculation were neither as large nor as consistent as yields from streaks sprayed with sulfuric acid, and inoculation efforts were finally abandoned.

In 1974, a shoot dieback, identified as pitch canker, reached epidemic proportions on slash pine in Florida plantations and seed orchards (14) and on loblolly pine in seed orchards in North Carolina and Mississippi (15). In several east-central Florida counties, more than 51% of the planted slash pines were infected (14). These outbreaks were of great concern to forest resource managers, and research on pitch canker disease was revived.

Pitch canker disease on southern pines now extends from Virginia to southern Florida and west to eastern Texas. Although the epidemic in Florida has subsided, pitch canker is still a problem in planted slash pines. An outbreak of shoot dieback on loblolly and pond (*P. serotina* Michx.) pines in plantations in eastern North Carolina is currently causing concern. Since 1974, the disease has been confirmed on loblolly, longleaf, shortleaf, slash, and Virginia pines in approximately 50 seed orchards.

Since pitch canker occurs sporadically in time and space, only the recovery phases of outbreaks are well documented.

Many investigators suspect that insects are vectors or wounding agents. The deodar weevil (*Pissodes nemorensis* Germar.) (6) and the pine-tip moth (*Rhyacionia* spp.) create wounds that may become infected by airborne spores of the pathogen. Wounds caused by the needle midge (*Contarinia* sp.) are common on loblolly pine in seed orchards and slash pine in plantations and are often colonized by FMS. The fungus does not grow into the shoots from the needles, but we believe needle infections serve as a source of inoculum for stem infections.

Hepting (17) suggested that some of the greatest damage resulting from fusiform rust on slash pine, caused by *Cronartium quercuum* (Berk.) Miy. ex Shirai f. sp. *fusiforme*, resulted from the rust being followed by *Dioryctria* larvae and the pitch canker *Fusarium*. We found that FMS rapidly colonizes rust-infected tissue and hastens mortality of slash and loblolly pine seedlings. Infection of rust galls by FMS (Fig. 4) further weakens stems of mature trees and increases chances of breakage and tree mortality. Recent mortality of Virginia pines in seed orchards and progeny tests may be caused in part by an increase in susceptibility to the pinewood nematode, *Bursaphelenchus xylophilus* (Steiner & Buhrer) Nickle, in trees having main stem cankers (12). We are studying involvement of pitch canker in these pathosystems.

Fig. 2. Shoot dieback of loblolly pine in a South Carolina seed orchard (1983).

Any fresh wound, regardless of cause or location, provides an infection court for the pathogen. In slash pine seed orchards, trunk cankers often develop following injuries caused by mechanical cone harvesters (Fig. 5A). The most obvious damage caused by these shakers is the removal of bark at the point where the pads grasp the trunk. Cankers, however, frequently develop at grasp sites showing no bark removal. Other routine practices in seed orchards, such as branch pruning, mowing, and, in the case of

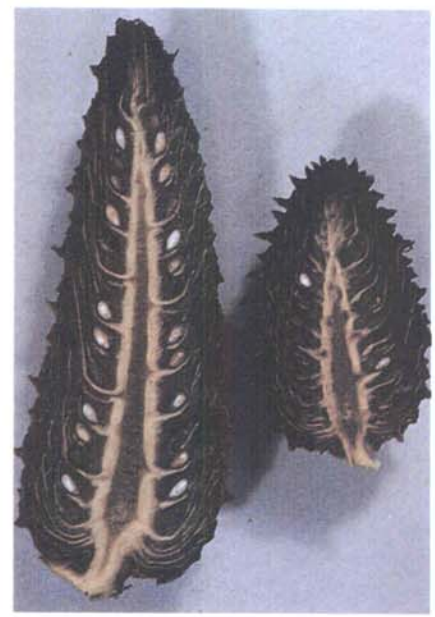

Fig. 3. Pine cone infected with *Fusarium moniliforme* var. *subglutinans* (right) is smaller and has fewer viable seeds than healthy pine cone (left).

Fig. 4. Fusiform rust gall on loblolly pine infected by pitch canker fungus.

loblolly pine, tearing cones from branches (Fig. 5B), create wounds for FMS to invade (11,12).

Weather-related injuries caused by wind and hail may also serve as entry points. Hurricanes and tornadoes in recent years have caused damage and contributed to the intensification of pitch canker in seed orchards of loblolly, shortleaf, and Virginia pines (11).

Inoculum seems to be available in all seasons of the year. In Florida, Blakeslee et al (5) reported that sporodochia (Fig. 6) containing macroconidia occurred routinely on infected branches within the upper crown of infected trees during all seasons of the year. In a related study on inoculum dispersal of FMS, inoculum was found to be present in the air year round, with maximum dispersal occurring during precipitation accompanied by turbulent air. In a loblolly pine seed orchard in North Carolina, Kuhlman et al (20) found spores of FMS throughout the growing season on dead branches in the crown, in rainwater falling through infected trees, and in the air.

Inoculation studies on loblolly pine in a seed orchard in North Carolina indicate that conditions are more conducive to infection from late summer through fall (20). Most dieback involves only the second flush, and often infections girdle the stem only after new growth starts (11,14,15).

Various stress factors may predispose trees to infection. Drought may have been associated with the 1974–1975 epidemics in Florida. However, moisture deficiency or early frost apparently was not involved in outbreaks of pitch canker in two loblolly pine seed orchards in Mississippi and North Carolina (15). Fertilizer application may predispose trees to infection. Late summer applications of ammonium nitrate to promote flowering may increase susceptibility of the hosts to the pathogen. In selected slash pine plantations in Florida, the incidence of pitch canker on slash pine increased following applications of fertilizer (26). However, the disease incidence remained high in adjacent unfertilized stands.

Each outbreak in each specific location has its own unique case history (or sequence of events). Care must be taken in extrapolating from one aspect of the disease to another (i.e., shoot dieback vs. trunk cankers and plantations vs. seed orchards).

Impact. Damage to southern pines by FMS includes tree mortality, growth suppression, stem deformation, seed and cone losses, and loss of seedlings in infected seedbeds and subsequent outplanting.

Slash pine stands are more severely infected by pitch canker disease than stands composed of other species. In a recent USDA Forest Service report, it was estimated that 551,500 acres of slash pine are infected with pitch canker, with an average incidence of 13.6% per affected stand. Slash pine volume lost to this disease was estimated to be 13.6–30.7 million cubic feet annually, with 70–80% caused by growth suppression. An estimated 2.5–3.4 million slash pine were rendered unusable for solid wood products because of stem malformation.

L. David Dwinell

Dr. Dwinell is a research plant pathologist at the USDA Forest Service Southeastern Forest Experiment Station in Athens, Georgia, and is associated with the Department of Plant Pathology at the University of Georgia in Athens. His research interests concern the etiology, epidemiology, and control of the pitch canker complex, fusiform rust, and pinewood nematode. He received degrees from Colorado State University and the University of Denver and, in 1967, his Ph.D. degree in plant pathology from Cornell University.

Jane B. Barrows-Broaddus

Dr. Barrows-Broaddus, also a research plant pathologist at the Southeastern Forest Experiment Station and associated with the Department of Plant Pathology at the University of Georgia, obtained her B.S. degree in botany and M.S. degree in plant pathology from the University of Georgia. In 1983, she received her Ph.D. degree in plant pathology from North Carolina State University. Her research responsibilities include diseases of southern pines in plantations and seed orchards, and her special research interests are the etiology and control of the pitch canker disease complex.

E. George Kuhlman

Dr. Kuhlman, also a research plant pathologist at the Southeastern Forest Experiment Station and associated with the Department of Plant Pathology at the University of Georgia, received a B.S. degree in botany from the University of Wisconsin and, in 1961, a Ph.D. degree in plant pathology from Oregon State University. He has investigated diseases caused by *Heterobasidion annosum* and *Phytophthora cinnamomi* at Asheville and Research Triangle Park, North Carolina. Recently, his research has involved hyperparasites of fusiform rust, etiology and epidemiology of pitch canker disease, and hypovirulence in the chestnut blight organism.

Although mortality can reach 25% in certain years, in some severely affected slash pine plantations the annual mortality is generally considered to be less than 2% (24).

In 1983, Kuhlman and Cade (Weyerhaeuser Company) surveyed loblolly and pond pines in plantations established on peat soils in eastern North Carolina and found that uninfected loblolly pines had significantly greater height and diameter than diseased trees. Healthy pond pines were also significantly taller than diseased trees, but the disease failed to influence diameter growth (*unpublished*).

Because of the variation in susceptibility to the disease and in production of cones and seed among clones in seed orchards, it is difficult to quantify disease damage in seed orchards unless seeds are collected by clones. At least part of an 86% decline in cone yield could be ascribed to pitch canker in one loblolly pine seed orchard in Mississippi (15). A comparison of cone yields in two adjacent loblolly pine orchards in South Carolina, one with shoot dieback and one without, indicates that a 28% reduction in cone yield in the affected orchard could be attributed to pitch canker (Dwinell, *unpublished*). Kuhlman et al (20), however, reported that cones initiated during a shoot dieback epidemic in a loblolly orchard in eastern North Carolina matured and resulted in a record cone and seed crop even on badly diseased clones. The impact on cone yield appears to vary from orchard to orchard, and no definitive conclusion can yet be drawn concerning the influence of shoot dieback on cone production.

In slash pine seed orchards, where main stem cankers are common, tree mortality is very low. The primary damage occurs when the trees break at the canker site during snow and ice storms. The life span of certain orchards is shortened because as more trees develop severe, perennial cankers, they are rogued out.

Screening of selected slash and loblolly pine seed lots has shown internal FMS contamination ranging from 0 to 11% (24). There have been occasions, however, when entire slash pine seed lots or an entire longleaf pine seed crop has been lost because of low viability and germination caused by infection of the seed by FMS (Dwinell, *unpublished*).

The Pathogen

Taxonomy. The causal agent has gone through a series of name changes. In 1946, this fungus was placed in the *Fusarium* section *Liseola* (18) but later was designated *F. lateritium* (Nees) emend. Snyd. & Hans. f. sp. *pini* Hepting (25). The latter name caused considerable taxonomic confusion when research on the disease was rekindled in the mid-1970s. Fusaria assigned to the section *Lateritium* typically have no microconidia or chlamydospores. In the 1970s, the most common isolate of *Fusarium* from pitch canker tissue had abundant microconidia in heads and no chlamydospores and were assigned to *Fusarium moniliforme* var. *subglutinans* in the section *Liseola* (10,14). These isolates were pathogenic to slash and loblolly pine seedlings, but isolates of eight other *Fusarium* species, including *F. lateritium*, were nonpathogenic to pines. Confirmation of FMS as the correct name was accomplished when five isolates from pine produced fertile perithecia in pairing with single ascospore isolates of *Gibberella fujikuroi* (Saw.) Wollenw. var. *subglutinans* Edwards (21). The teleomorph, however, is found only in culture. Therefore, sexual compatibility cannot be used for routine identification because sexually infertile isolates are more common than fertile ones. In 1983, a proposal to raise the variety to species level as *F. subglutinans* (Wollenw. & Reink.) Nelson, Toussoun, & Marasas was made on the basis of the presence of polyphialides and the absence of microconidial chains (23). Based on microconidial ontogeny, isolates designated *F. moniliforme* Sheld. var. *moniliforme* are distinctly different from isolates of FMS, whereas isolates designated *F. moniliforme* var. *intermedia* Neish & Leggett (= *F. proliferatum* (Matsushima) Nirenberg) have characteristics intermediate between the two varieties (19). Therefore, we suggest that varietal names be retained to indicate this continuum within the section in both the anamorph and the teleomorph states.

Morphology. Isolates of FMS grown on all media produce large numbers of microconidia in heads. Isolates grown on water agar with or without carnation leaves (CLA) or oat grains produce abundant heads that are readily observed under low magnification (×100). On these weak media, heads contrast strongly with chains of microconidia produced by other varieties. Microconidia are formed by phialides and polyphialides. Phialides occur in young cultures on all media, whereas polyphialides are more commonly seen in 10- to 14-day-old cultures on enriched media (e.g., potato-dextrose agar) or in 7-day-old cultures on weak media. The CLA medium is ideal for viewing polyphialides. Microconidia may be 0–3 septate. The presence of microconidia of different sizes is an indication that the isolate may be FMS. Macroconidia, common on most media, including weak ones, are commonly used for identification to the genus level.

Variation. Although FMS occurs on a wide range of hosts and is found in many areas of the world, not all strains of the fungus are pathogenic to pines. A pathogenicity study on FMS from various nonpine hosts found only isolates

from gladiolus corms capable of infecting slash and loblolly pines, while 17 other isolates from corn, *Dracaena*, sycamore, pecan, lily, *Araucaria*, and *Amaryllis* were avirulent on pine (13).

We have isolated FMS from forest soils, surfaces of pine needles, branches, and boles and from bark and debris adhering to the tree-shaker pads. Pathogenicity tests with these isolates on slash and loblolly pines indicate that FMS occurs naturally in mixed populations of pathogenic and saprophytic strains. Isolates of FMS can be identified as the pitch canker pathotype only if their pathogenicity is demonstrated by inoculating pine seedlings.

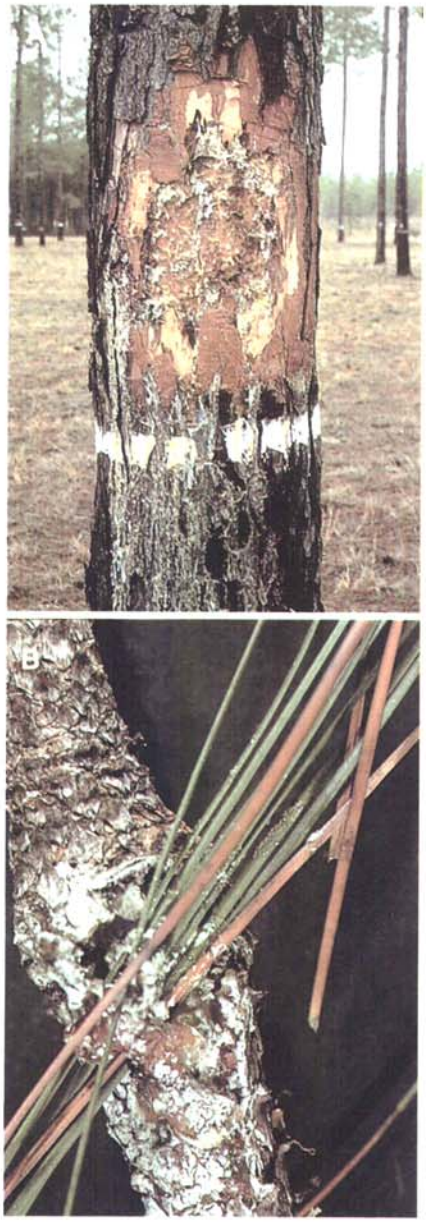

Fig. 5. (A) Slash pine in seed orchard shows pitch canker (bark removed) resulting from wounding by mechanical shaker used for harvesting cones. (B) Needles embedded in resin on face of pitch canker on loblolly pine branch associated with wound created during cone collection.

There is considerable variation within pathogenic populations of FMS. The variation, however, generally appears to be among isolates rather than among geographic or pine host sources of the isolates. Pathogenic races of the pitch canker fungus have not been identified, but our continued research may demonstrate the existence of pathogenic specialization.

Control Strategies

No specific program has been developed to reduce or eliminate the threat of pitch canker disease. An integrated management approach, including chemical control, biocontrol, genetic selection for resistance, and altered cultural practices, is being developed.

Chemical control. In nurseries, seed orchards, and Christmas tree plantations, where intensive management is commonly practiced, chemical control is economically feasible. Initial trials with thiabendazole on loblolly pine seedlings previously inoculated with FMS have been successful in preventing infections (9). We are testing thiabendazole as a topical spray on trunk wounds; as a foliar spray protection of female flowers, cones, and seeds; and as an injected systemic therapeutic for trunk cankers.

Indirect chemical control of FMS-caused pine diseases may sometimes be achieved by applying insecticides to reduce the number of wounding agents and/or vectors for the pathogen. Wilkinson et al (26) observed that phorate insecticide treatments to control tip moth were consistently associated with lower incidences of pitch canker in slash pine plantings in Florida. In our field trials on 5-year-old slash pine in Florida, plots sprayed with the insecticide Dursban M (chlorpyrifos) had a significantly lower pitch canker incidence than all other treatments, including benomyl sprays. Trees treated with benomyl had as much dieback as the controls (Dwinell and Barrows-Broaddus, *unpublished*). Because conelet abortion and seed deterioration caused by FMS are intimately associated with feeding by seedbugs (*Leptoglossuss corculus* Say, *Tetrya bipunctata* H.-S.), seedworms (*Laspeyresia* spp.), and seed chalcids (*Megastionus atedius* Walker) (8), control of these insects with certified insecticides may play an important role in controlling pitch canker disease of female strobili, conelets, and seed.

Fig. 6. Sporodochia of pitch canker fungus in needle scars on loblolly pine shoot.

Biological control. Microorganisms have potential as biocontrol agents for reducing disease incidence. Strains of *Arthrobacter* sp., an inhabitant of diverse habitats, are antagonistic to FMS in vitro (Fig. 7). Strains of this bacterium have been recovered from the soil and canopy in southern pine plantations and seed orchards (4). Although in field trials *Arthrobacter* did not protect inoculated wounds from colonization, some strains did reduce subsequent conidial production on these wounds. Since tested *Arthrobacter* isolates varied considerably in efficacy, more effective strains should be sought. A practical control program will not be feasible until a strain is found that will consistently control FMS.

Another approach to biocontrol is to apply avirulent competitors to the infection courts of FMS. One promising candidate, *F. moniliforme* var. *moniliforme* (FMM), has been recovered from slash pine bark loosened by tree shakers (11). When inoculated on slash and loblolly pine seedlings, isolates of this fungus are avirulent or weakly virulent (13). Preliminary results from field trials indicate that wounds inoculated with FMM prior to inoculation with FMS later yield mostly FMM from surface washes and wound isolations (Barrows-Broaddus, *unpublished*). FMM has been isolated from longleaf and loblolly pine seedlings with damping-off and from second-year loblolly cones. Therefore, caution must be exercised in using as biocontrol agents organisms that are closely related to the pathogen until their relationship to diseases of strobili, seeds, and seedlings has been determined.

Resistance. Variation in pitch canker incidence is very common among clones within seed orchards (11,20). All ramets of some clones remain free from disease, while ramets of other clones have extensive dieback, suggesting that there may be sufficient genetic variation in host susceptibility to use resistance as a means of control. In a loblolly orchard in North Carolina, clones expressed levels of resistance in an inoculation study similar to those caused by natural infection (20). Inoculated seedlings of slash and loblolly pines developed from open-pollinated families varied considerably in their

susceptibility to FMS. There was no correlation between the response of 12 loblolly families tested and the disease incidence of the parent clones. Further work is needed on additional families to determine if resistance is a weakly inherited trait. Field progeny tests must be well designed because stress, insects, host nutrition, and host physiology will complicate evaluations of resistance in the host-pathogen interaction.

The relative susceptibility of southern pines has been defined in greenhouse studies using inoculated seedlings. Rankings were as follows: Virginia (Fig. 8) and shortleaf pines, highly susceptible; slash, loblolly, and pitch pines, moderately susceptible; and pond and eastern white pines, relatively resistant (3,10). These rankings often change in field trials; species ranked as relatively resistant frequently develop a high incidence of disease under the influence of environmental stress and inoculum pressure. Loblolly pine was once considered immune to the disease, and severe damage to pond pine has been observed recently.

Within pine species, the incidence of pitch canker is frequently related to the geographic source or provenance of the host. In three seed orchards on the Coastal Plain, for example, incidence of pitch canker of loblolly pines was more frequent on Piedmont than on Coastal Plain sources (15). Blakeslee and Rockwood (7) reported that slash pine clones from central Florida were more disease-resistant than clones from other geographic areas.

A histological study was conducted on greenhouse-grown pine seedlings to determine the anatomical basis for the variation in host resistance (3). The results showed that the speed and degree of host response to wounding were the key factors for individual plants to partially resist infection by the fungus. The response to injury, whether caused by wounding or by infection by the pathogen, was similar for all pines tested. Field experiments should be conducted to find if plantation and seed orchard environments influence the resistance responses observed in greenhouse trials.

Since economic impacts are currently confined to seed orchards and Christmas tree plantations, developing resistance to the pitch canker complex in southern pines may not be feasible. If pitch canker disease ever becomes pandemic in slash and loblolly pine plantations, the selection for resistant material will probably become the primary means for disease control.

Cultural control. Fertilization in the middle of the growing season with ammonium nitrate to stimulate female strobilus production probably aggravates pitch canker problems in seed orchards. Fraedrich and Witcher (16) found that canker length was increased by applications of complete fertilizer (N-P-K) and speculated that nitrogen was the principal nutrient responsible for increased canker severity.

Fig. 7. Inhibition of *Fusarium moniliforme* var. *subglutinans* by *Arthrobacter* sp. in vitro.

Harvesting of slash and loblolly pine cones produces wounds during the optimum infection period in the fall and can result in multiple infections throughout the tree. Pitch cankers develop not only on the stem where the shaker pads attach but also on the upper portion of the trunk where the vibration (or whiplash) of the main stem is most vigorous. Tree shakers should be properly maintained and carefully operated during harvest to minimize such damage. Loblolly pine cones are usually harvested by removing individual cones from the branches. Damage can be minimized by clipping instead of tearing off cones. Because damage to the tree is inevitable with tree shakers and with clipping, such alternate harvesting procedures as the use of nets for seed collection should be considered.

Harvested cones should be handled in ways that reduce the hazard of seed deterioration. In seed-processing plants, cones are often stored in open bins prior to seed extraction in the drying kiln. At one plant we visited last fall, many of the cones were covered with mold, and we isolated FMS from the scales and seeds in these cones. Special care should be taken to protect cones from excessive moisture and to provide continuous flow of air around all cones during storage. Samples of seed lots from orchards with pitch canker should be x-rayed to estimate the percentage of deteriorated seed. Unsound seeds with internal fungi can be identified in a radiograph. Procedures have been developed to remove these seed from seed lots (8).

Selection of seed sources and planting sites and the quality of nursery seedlings influence the risk of pitch canker outbreaks in plantations. When pitch canker occurs in nurseries, diseased seedlings should be culled during seedling harvest to avoid spreading the disease to the plantation. When outplanting seedlings, site selection should be carefully considered. Planting trees from distant sources may be risky. A pitch canker epidemic on 20,000 acres in north central Florida in the mid-1970s was partially

Fig. 8. Pitch canker developing at branch stubs on Virginia pine that had been inoculated with the causal fungus.

attributed to the planting of seeds obtained from Georgia. The quality of the site may also affect the trees' susceptibility. Barnett and Thor (2) observed that susceptibility to pitch canker increased on Virginia pines planted on a poorly drained site.

Fungicides that might be used to directly control pitch canker disease currently are not registered for use in seed orchards. Several that might work lack pesticide certification in pine orchards. Therefore, chemical control of the disease is currently limited to certified insecticides used against suspected wounding and vectoring insects. The most immediate and practical control measures available to the forester are the modification of cultural practices to reduce the threat of disease while maintaining the beneficial effects of these cultural practices on the abundant production of quality timber and disease-free seeds.

Because the impact of pitch canker is of particular concern in seed orchards, research on the disease complex in seed orchards is being emphasized. The current thrust of USDA Forest Service research is directed at the infection process and the impact of the disease on the reproductive structures of loblolly, longleaf, and slash pines. We are learning how seed orchard management practices and environmental factors are affecting disease incidence.

Literature Cited

1. Barnard, E. L., and Blakeslee, G. M. 1980. Pitch canker of slash pine seedlings: A new disease in forest tree nurseries. Plant Dis. 64:695-696.
2. Barnett, P. E., and Thor, E. 1978. Effects of site and inheritance on *Fusarium* incidence in Virginia pine. Pages 159-161 in: Proc. Symp. Manage. Pines Interior

South. U.S. Dep. Agric. For. Serv. State Private For. Tech. Publ. SA-TP2.
3. Barrows-Broaddus, J., and Dwinell, L. D. 1983. Histopathology of *Fusarium moniliforme* var. *subglutinans* in four species of southern pines. Phytopathology 73:882-889.
4. Barrows-Broaddus, J., Teeslink, S. D., and Kerr, T. J. 1983. Characterization of *Arthrobacter* strains isolated from the pine environment that inhibit *Fusarium moniliforme* var. *subglutinans*, the causal agent of pine pitch canker. Can. J. Microbiol. 29:1382-1389.
5. Blakeslee, G. M., Kratka, S. H., Schmidt, R. A., and Moses, C. S. 1978. Sporodochia of the pitch canker fungus (*Fusarium moniliforme* var. *subglutinans*) as found in diseased slash pines in Florida. Plant Dis. Rep. 62:656-657.
6. Blakeslee, G. M., Oak, S. W., Gregory, W., and Moses, C. S. 1978. Natural association of *Fusarium moniliforme* var. *subglutinans* with *Pissodes nemorensis*. (Abstr.) Phytopathol. News 12:208.
7. Blakeslee, G. M., and Rockwood, D. L. 1978. Variation in resistance of slash pine to pitch canker caused by *Fusarium moniliforme* var. *subglutinans*. (Abstr.) Phytopathol. News 12:207.
8. Bramlett, D. L., Belcher, E. W., Debarr, G. L., Hertel, G. D., Karrfalt, R. P., Lantz, C. W., Miller, T., Ware, K. D., and Yates, H. O. 1977. Cone analysis of southern pines. U.S. For. Serv. Southeast. For. Exp. Stn. & Southeast. Area State Private For. Gen. Tech. Rep. SE-13.
9. Bruck, R. I. 1983. Effects of thiabendazole on pitch canker of loblolly pine. (Abstr.) Phytopathology 73:834.
10. Dwinell, L. D. 1978. Susceptibility of southern pines to infection by *Fusarium moniliforme* var. *subglutinans*. Plant Dis. Rep. 62:108-111.
11. Dwinell, L. D., and Barrows-Broaddus, J. 1981. Pitch canker in seed orchards. Pages 234-240 in: Proc. South. Tree Improv. Conf. 16th.
12. Dwinell, L. D., and Barrows-Broaddus, J. 1983. Pine wilt and pitch canker of Virginia pine in seed orchards. Pages 55-62 in: Proc. South. Tree Improv. Conf. 17th.
13. Dwinell, L. D., and Nelson, P. E. 1978. Susceptibility of slash and loblolly pines to strains of *Fusarium moniliforme* and its variety *subglutinans*. (Abstr.) Phytopathol. News 12:207.
14. Dwinell, L. D., and Phelps, W. R. 1977. Pitch canker of slash pine in Florida. J. For. 75:488-489.
15. Dwinell, L. D., Ryan, P. L., and Kuhlman, E. G. 1977. Pitch canker of loblolly pine in seed orchards. Pages 130-137 in: Proc. South. For. Tree Improv. Conf. 14th.
16. Fraedrich, B. R., and Witcher, W. 1982. Influence of fertilization on pitch canker development on three southern pine species. Plant Dis. 66:938-940.
17. Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. U.S. Dep. Agric. For. Serv. Agric. Handb. 386. 658 pp.
18. Hepting, G. H., and Roth, E. R. 1946. Pitch canker, a new disease of southern pines. J. For. 44:742-744.
19. Kuhlman, E. G. 1982. Varieties of *Gibberella fujikuroi* with anamorphs in *Fusarium* section *Liseola*. Mycologia 74:759-768.
20. Kuhlman, E. G., Dianis, S. D., and Smith, T. K. 1982. Epidemiology of pitch canker disease in a loblolly pine seed orchard. Phytopathology 72:1212-1216.
21. Kuhlman, E. G., Dwinell, L. D., Nelson, P. E., and Booth, C. 1978. Characterization of the *Fusarium* causing pitch canker of southern pines. Mycologia 70:1131-1143.
22. Miller, T., and Bramlett, D. L. 1979. Damage to reproductive structures of slash pine by two seed-borne pathogens: *Diplodia gossypina* and *Fusarium moniliforme* var. *subglutinans*. Pages 347-355 in: Proc. Symp. Flowering Seed Dev. Trees. U.S. Dep. Agric. South. For. Exp. Stn.
23. Nelson, P. E., Toussoun, T. A., and Marasas, W. F. O. 1983. *Fusarium* Species: An Illustrated Manual for Identification. Pennsylvania State University Press, University Park. 193 pp.
24. Oak, S. W., McClure, J. P., and Glover, J. F. 1982. Areas affected and losses caused by pitch canker disease, 1980. U.S. Dep. Agric. For. Serv. State Priv. For. For. Pest Manage. Rep. 82-1-38. 27 pp.
25. Snyder, W. C., Toole, E. R., and Hepting, G. H. 1949. Fusaria associated with mimosa wilt, sumac wilt, and pine pitch canker of southern pines. J. Agric. Res. 78:365-382.
26. Wilkinson, R. C., Underhill, E. M., McGraw, J. R., Pritchett, W. L., and Schmidt, R. A. 1977. Pitch canker incidence and fertilizer-insecticide treatment. Inst. Food Agric. Sci. Univ. Fla. Prog. Rep. 77-1. 4 pp.