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PITCH CANKER OF SOUTHERN PINES[1]

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INTRODUCTION: Since its initial description in 1946 (Hepting and Roth 1946), pitch canker of southern pines, caused by *Fusarium circinatum* Nirenburg and O'Donnell [=*Fusarium subglutinans* (Wollenw. & Reinking) Nelson, Toussoun & Marasas] was generally regarded as a disease of intermediate to older-aged trees. However, recent investigations (Barnard and Blakeslee 1980; Carey *et al.* 2005; Dwinell *et al.* 1985; Matthews 1962) have revealed that *F. cirninatum* can cause damage to susceptible pines at essentially any point during their life cycles (flower, seed, seedling, mature tree). Infections and associated damages vary depending upon the age, genetic susceptibility, location, and condition of host pines as well as the specific locus (loci) of infection(s) within affected trees. For example, 1) pine cones and seeds can be infected and destroyed by *F. circinatum* (a potential and periodic problem in high-value commercial forest seed orchards), 2) infected and/or contaminated seed can lead to mortality of seedlings in nursery seedbeds, 3) seedling infection can result in death of young trees in newly established plantations, and 4) infections in older trees cause stem and crown deformation, proportionate reductions in tree growth, reduced cone/seed production capacity, susceptibility to wind breakage and occasional tree mortality.

The pitch canker fungus is endemic to the southeastern U.S. and is known in many other parts of the world (Correll *et al.* 1991; Dwinell *et al.* 1985; Gadgil *et al.* 2003; Sinclair and Lyon 2005; Storer *et al.* 1994). Virtually all southern pines are susceptible to infection. Epidemics/outbreaks of pitch canker are sporadic in time and space, although the frequency and severity of disease outbreaks have increased with the intensity of forest management practices. The most recent severe epidemic occurred in slash pine (*Pinus elliottii* Engelm.) plantations in east central Florida during the mid 1970s where recorded disease incidence levels exceeded 90% and mortality approached 25% in some stands (Blakeslee and Oak 1979). More recently, a number of limited epidemics have begun to develop in loblolly pine (*Pinus taeda L.*) plantations in several southeastern states (Kuhlman and Cade 1985). In Florida, pitch canker has become a potentially menacing problem in the artificial regeneration of pine plantations, causing varying and sometimes unacceptable levels of mortality in first-year outplanted seedlings. To date, such problems have been largely confined to situations where susceptible pines are planted on sites recently converted from agricultural uses (row crops, esp. legumes, citrus, etc.). However, infections by the pitch canker fungus in 2001 resulted in an estimated 5000 acres of outplant failure on cutover forest sites in slash pine seedlings from one Florida nursery (Barnard, unpublished). Pitch canker outbreaks are often most damaging where susceptible pines are exposed to conditions of high soil or aerosol fertility and/or severe water stress (Claeson and Smith 1977; Fisher *et al.* 1981; Schmidt *et al.* 1976). For example, severe disease episodes have been observed on pines in 1) close proximity to poultry farms, 2) excessively fertilized pine plantations, 3) stands fertilized and/or irrigated with nutrient laden industrial wastes (organic and inorganic), and 4) intensively managed landscape environments such as golf courses. In one notable scenario, the pitch canker pathogen was involved in the mortality of mature longleaf pines (*Pinus palustris* Mill.) exposed to nitrogenous emissions (esp. NH_3) from a chemical plant.

RECOGNITION OF THE DISEASE: Pitch canker is usually first detected in mature trees by the appearance of characteristic reddening or "flagging" of infected terminal or lateral shoots. Dying shoots appear most frequently from late fall through spring. Infected shoots typically exude copious amounts of resin (pitch) at or near infection loci. Internally, infected tissues are necrotic and xylem (wood) tissues are impregnated with resin, the degree of resinosis being variable among different host pines. Infected shoots usually die within a matter of months due to the girdling action of the pathogen. Old infections can often be identified by the dull gray-brown appearance of the dead shoots and needles. Dead shoots often persist for months and even years. Dead needles frequently adhere for extended periods of time because they are often matted and stuck in exuded resin (Fig. 1).

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Fig. 1. Evidence of pitch canker infection in mature pines. A) Mortality ("flagging") of infected terminal and branch shoots in slash pine crowns. B) External resinosis on infected slash pine branch. C) Internal resin impregnation of infected xylem (wood) tissues. D) Sporodochia of *Fusarium circinatum* produced in needle fascicle scars on infected tissues. (Photography credits: A – E.L. Barnard, B-D – G.M. Blakeslee)

Main stem cankers on larger trees may or may not be lethal, depending upon the location, number, and severity of individual cankers. If complete stem girdling results from the infection(s), the stem above the canker(s) will die. Smaller, non-girdling cankers can be perennial in nature, remaining active for several years and sometimes causing depressed canker faces (*i.e.*, areas of restricted diameter growth due to the death of the cambium). Main stem cankers are also characterized by external resinosis and internal resin impregnation of associated xylem tissues (Blakeslee *et al.*1980).

In forest and ornamental tree nurseries, *F. circinatum* infections may be manifested as pre- and post-emergence damping-off, sudden wilt and death of young succulent seedlings, seedling tip blights (*e.g.*, necrosis of terminal shoots distal to purplish, constricted lesions on seedling stems), and late season mortality of older, woody seedlings. Woody seedlings (1-2 years of age, sometimes older in plantings of Virginia pines, *Pinus virginiana* Mill.) in both nursery and outplant settings often are infected at or near the ground-line. Associated resin exudation often results in the development of distinct aggregations of soil particles attached to seedling stems and roots at the point(s) of infection. Internally, infected stems typically exhibit distinct resin-impregnated lesions at infection loci (Fig. 2). Individual infected seedlings in nurseries and field settings usually occur in a widely scattered, random pattern. Occasionally, in forest tree nurseries, small clusters of infected seedlings appear (typically 1-2 dead seedlings surrounded by several dying seedlings), apparently due to secondary seedling-to-seedling spread of the pathogen (Barnard and Blakeslee 1980).

Fig. 2. Root collar and tap root resinosis in A) nursery, and B-C) outplanted sand pine [*P. clausa* (chapm.) Vasey] seedlings infected with *Fusarium circinatum*. Note soil aggregations adhering to infected seedlings and internal resin impregnation of infected xylem tissues. (Photography credits: A – G.M. Blakeslee, B-C – E.L. Barnard)

The pitch canker fungus causes mortality of female strobili (flowers) and mature cones, as well as the deterioration of seeds (Barrows-Broaddus 1987; Carey *et al.* 2005; Miller and Bramlett 1979). Infected cones exhibit a variety of symptoms (variable among species of pine) including 1) distorted, smaller than usual cones, 2) purplish

discoloration of cone scales on otherwise green cones, 3) necrotic cone tips and 4) resinous external lesions. Infected/contaminated seed is not easily identified. Damaged seeds can be detected through screening of seedlots by radiography, but laboratory isolation is required to confirm the presence of *F. circinatum* in seed and in cones.

INFECTION BIOLOGY: Pitch canker infections are initiated by microscopic spores called conidia. Conidia are produced in small (< 3mm) salmon-orange, wart-like fruiting bodies (*sporodochia*, sing. = *sporodochium*), which are produced on dead or dying branches, often in needle fascicle scars (Fig. 1.) or on stems of infected seedlings (Barnard and Blakeslee 1980; Blakeslee *et al.* 1978). Conidia are also produced by the fungus in and around the chip cocoons and galleries constructed by the eastern pine weevil (*Pissodes nemorensis* Germar) beneath the bark of dead/dying pines. Infections may occur throughout the year, but most commonly occur during the late summer and fall. At that time of year in much of the southern U.S., violent thunderstorms are common and spore dispersal is enhanced by the action of accompanying wind and rain (Kuhlman *et al.* 1982; Blakeslee – unpublished). It is also during that time of year that the eastern pine weevil species (*Pissodes nemorensis* Germar), a known vector of *F. circinatum*, feeds on the susceptible green shoots of slash pine, often introducing the fungus into its feeding wounds.

The pitch canker fungus is a wound pathogen and normally does not penetrate intact pine tissues. Thus, infections are commonly associated with environmental (storm damage, etc.), man-made (cone harvest scars and tree shaker wounds in seed orchards, Christmas tree shearing wounds, etc.), and insect-created injuries (*P. nemorensis*, pine coneworms – *Dioryctria* spp.; pine tip moths – *Rhyacionia* spp., etc.) (Dwinell *et al.* 1985; Matthews 1962). Evidence indicates that the pitch canker fungus is introduced into forest tree nurseries on infected or contaminated seeds (Carey *et al.* 2005), although introduction via airborne inoculum (spores) is theoretically possible.

DISEASE MANAGEMENT: Prevention is the most effective means of reducing losses to *F. circinatum*. Good silvicultural practices are recommended for forest stands, *e.g.*, use of *Pinus* spp. best adapted to specific sites; use of more resistant *Pinus* spp. and/or genetically resistant planting stock (Rockwood *et al.* 1988), if available for areas with historical or anticipated high disease pressure; avoidance of water stress induced by excessive or unnecessary site drainage; thinning of overstocked and/or diseased plantations; and avoidance of excessive and/or unnecessary stand fertilization (Blakeslee *et al.* 1992; Blakeslee *et al.* 1999). Ornamental pines should be grown as much as possible with minimal exposure to landscape fertilization and irrigation. Sanitation (*i.e.*, removal and/or destruction of diseased pines or infected branches) may be useful in the reduction of local inoculum. This practice is especially recommended for commercial forest seed orchards in order to minimize the potential for flower, cone, and seed infections. To date, proven cost-effective fungicidal controls are unknown.

SURVEY AND DETECTION: Examine mature trees for dead/dying ("flagging") branch and stem shoots, especially during the late fall through spring. External resinosis and internal resin-soaking of xylem tissues at infection loci are characteristic. Examine lower stems and root collars (including upper tap roots) of dead/dying seedlings for adhering resin/soil aggregations. Longitudinal dissection of infected seedling stems typically reveals a distinct resin-soaked lesion at or near the point of infection.

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