Annosum Root Rot of Pines in Florida[1]

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INTRODUCTION: Annosum root rot, caused by the fungus *Heterobasidion annosum (Fr.:Fr.)* Bref. *[syn. Fomes annosus (Fr.:Fr.)* Cooke; *Fomitopsis annosa (Fr.:Fr.)* P. Karst.] is considered among the most important and destructive diseases affecting conifers in the north temperate regions of the world (Alexander and Anderson 1985; Hodges 1969; Sinclair *et al.* 1987). Some 200 woody species, including several angiosperms, are reported hosts of *H. annosum* (Sinclair *et al.* 1987); the most common belong to the genera *Abies, Juniperus, Larix, Picea, Pinus, Pseudotsuga,* and *Tsuga* (Hodges 1969). Annosum root rot occurs in both natural and planted forest stands, but is most prevalent and serious in stands following thinning or harvest operations (Powers and Boyce 1961; Powers and Verrall 1962; Sinclair *et al.* 1987). *Heterobasidion annosum* causes tree mortality (Anderson and Mistretta 1982; Applegate 1971; Driver and Dell 1961; Morris 1970; Powers and Verrall 1962), reduced growth rates (Alexander *et al.* 1981; Bradford *et al.* 1978; Froelich *et al.* 1977), increased susceptibility to attack by bark beetles (Alexander *etal.* 1980, 1981), and regeneration failure (Driver and Ginns 19646; Hendrix *et al.* 1964; Kuhlman 1986), all of which have been documented in infected pine stands in Florida (Barnard, unpublished). While soils in much of northern Florida are classified as "high hazard" for annosum root rot (Alexander and Anderson 1985), and the pathogen is endemic (Barnard *et al.* 1985, 1991), major tree/timber losses are apparently sporadic (Barnard, unpublished; Barnard *et al.* 1991). However, risk of losses to annosum root rot can logically be expected to increase if thinnings and other intermediate or selection harvests become more prevalent.

SYMPTOMS: Infected pine stands are characterized by: dead and/or dying trees; trees with thin, discolored, or otherwise unthrifty foliage/crowns; and/or leaning or completely uprooted, windthrown trees (live or dead) due to fungus-decayed root systems. Detection of infected roots is often enhanced by clumps of resin-impregnated soil which frequently adhere to same. Internally, infected roots display varying patterns of staining, resin impregnation, and decay depending on host and stage of disease development (Fig. 1). Caution is advised at this point with respect to definitive diagnosis as these symptoms are generic and may be the result of infection by a variety of other root disease fungi (Barnard *et al.* 1985, 1991; Barnard and Meeker 1995). Advanced and usually diagnostically definitive decay is typified by small elongated white pockets (sometimes with attendant black spots or flecks) that eventually coalesce and produce a "white stringy rot" reminiscent of "shredded wheat" *sensu* Barnard (Boyce 1961; Hodges 1974; Robbins 1984). Diagnosis is sometimes aided by the occurrence of dead and/or dying redcedars *(Juniperus* spp.) in the understory. Redcedars are highly susceptible to *H. annosum* (Hodges and Kuhlman 1974).

Fig. 1 Symptoms *of* annosum root rot in slash pine. A) Crown thinning in infected tree (center). B) Windthrown live tree. C) Incipient resinosis with associated clump *of* resin-impregnated soil. D) Resin-soaked root xylem. F) White stringy rot ("shredded wheat") indicative of advanced infection: usually definitive for annosum root rot.

PATHOGEN BIOLOGY AND RECOGNITION: Long range dispersal of *H. annosum* is effected by means of airborne basidiospores. These spores are produced in basidiomata (fruiting bodies; "conks") which develop on infected roots and stumps or at the bases of infected trees beneath the duff or needle litter. Basidiomata (sing.; basidioma) are

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leathery in texture with grayish-brown to dark brown upper surfaces, and creamy white, minutely poroid lower surfaces which sometimes darken with age. Basidiomata vary from smooth to wrinkled or deeply convoluted and often grow intermingled with pine needles and duff from the forest floor (Fig. 2). They vary in size from small nubs to brackets up to several centimeters wide (Froelich *et al.* 1977; Hodges 1974; Robbins 1984). Although innately perennial, basidiomata of *H. annosum* are often difficult to find because of their variable production and sometimes rapid decomposition. Basidiospore production is highly seasonal. In the South, spore production is abundant from fall to spring, but drops to near zero with the onset of higher summer temperatures (Ross 1973).

Basidiospores germinate on the surfaces of freshly cut stumps of susceptible hosts, although this process is presumably limited in Florida by extended periods of high temperatures lethal to the fungus' propagules (Driver and Ginns 1964a; Gooding *et al.* 1966; Ross 1969). If able to successfully germinate, the fungus colonizes stump tissues, proceeds into stump roots, and eventually progresses via root contacts and grafts into the root systems of adjacent residual trees.

The fungus grows vegetatively within roots in infected stands at approximately 1-2 m/year, resulting in typical root disease "infection centers" with expanding radii (Froelich *et al.* 1977; Hodges 1969; Hodges 1974). While this process accounts for the majority of infections and the disease's strong relationship to thinned stands, there is evidence that infections also arise from direct penetration of roots by germinating basidiospores or the asexual spores (conidia, sing.; conidium) of the pathogen's imperfect stage, *Spiniger meineckullum (A.* Olson) Stalpers (syn. *Oedocephalum lineatum* Bakshi) (Hendrix and Kuhlman 1964; Kuhlman 1969).

Fig. 2 Basidiomata *of H. annosum. A)* Basidioma (beneath knife blade) at base of infected tree exposed by removal of duff/litter. Note irregular shape and whitish undersurface. B) Small bracket-like basidiomata (right of pen) at base of infected stump. Note brownish upper surfaces and white margins/undersurfaces.

Heterobasidion annosum is influenced by numerous edaphic and biotic factors. Greatest pathogen and disease development generally occurs on sites with deep, well-drained, sandy or sandy-loam soils with low organic matter and relatively high pH values. Conversely, sites characterized by heavier soils, lower pH values, more organic matter, and poor internal drainage or high water tables tend to inhibit, although not necessarily exclude, development of the fungus (Alexander *et al.* 1975, Froelich *et al.* 1966, Kuhlman *et al.* 1976, Morris and Frasier 1966). The activity of *H. annosum* is also suppressed by competitive fungi such as *Phanerochaete gigantea (Fr.:Fr.)* S. S. Rattan *et al.* [syn. *Peniophora gigantea (Fr.:Fr.)* Massee; *Phlebia gigantea (Fr.:Fr.)* Donk] and *Trichoderma* spp. (Boyce 1963; Driver and Ginns 1969), and perhaps by *Fomitopsis palustris* (Berk. et Curt.) Gilbn. and Ryv., a common colonizer of pine stumps in Florida (Barnard *et al.* 1991, Gilberston and Ryvarden 1986).

OCCURRENCE, IMPACT, AND INTERACTION WITH PINE BARK BEETLES: The full extent and impact of annosum root rot infections in Florida are, at best, difficult to assess. A 1978 survey of 14 North Central Florida counties (Barnard, unpublished) revealed reports of *H. annosum* in eight of 64 slash pine *(P. elliottii* Engelm.) plantations thinned over the previous 10 years. Twenty-three additional plantations were reported to be exhibiting symptoms typical of annosum root rot. A subsequent formal survey of thinned slash pine plantations (Barnard *et al.* 1991) detected *H. annosum* in 17 of 30 plantations across northern Florida. However, in only one of these plantations was annosum root rot considered problematic. Indeed, precise analysis of the root disease(s) and associated symptoms and impacts in the surveyed plantations was confounded by the frequent and coincident occurrence of several other known pine root pathogens, including *Armillaria tabescens* (Scop.) Dennis, Orton and Hora, *Phaeolus schweinitzii (Fr.:Fr.)* Pat, *Inonotus circinatus (Fr.)* R.L. Gilbertson, and *Leptographium procerum* (Kendrick) M. J. Wingfield.

Serious annosum root rot infections, necessitating remedial and/or stand salvage harvests, have been observed in individual stands in Walton, Jackson, Leon, and Columbia counties (Barnard, unpublished). Two slash pine stands and one loblolly *(P. taeda* L.) pine stand had been previously thinned, but one slash pine stand had no thinning or applicable harvest history. In two of the cases, landowners had been responding to bark beetle *(Ips* spp.) infestations that had in fact been precipitated by annosum root rot. In yet another thinned slash pine stand (Suwannee county) riddled by southern pine beetles *[Dendroctonus frontalis* (Zimmerman)], evidence of previous annosum root rot activity was widespread. Untrained observers often assume they have a bark beetle problem in symptomatic stands, disregarding the real problem ------ "invisible" (underground) root disease. Accordingly, bark beetle infestations in pine stands should be considered in light of the possibility of antecedent root disease. Questions regarding thinning and/or harvest histories should be raised, and where appropriate, roots should be excavated and examined (see Fig. 3).

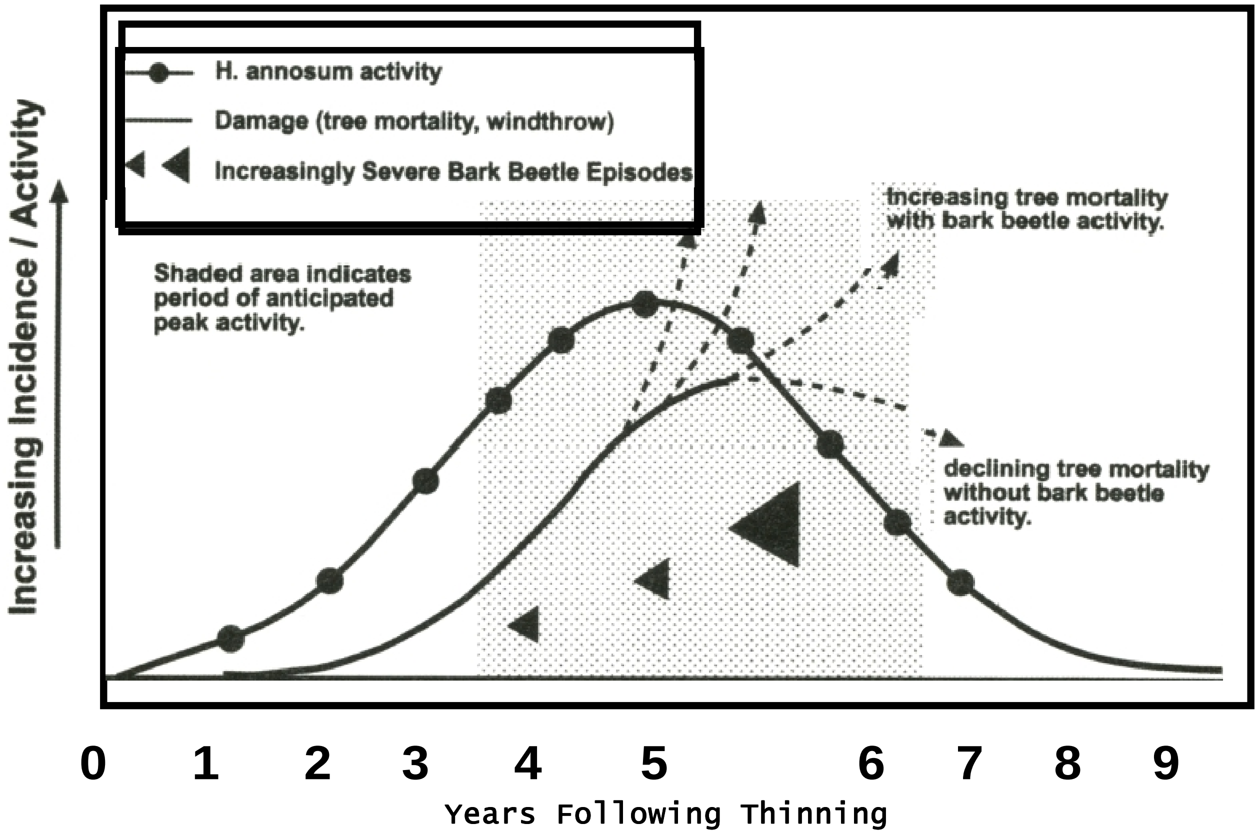

Fig. **3** Conceptual model showing interaction(s) between annosum root rot and pine bark beetle infestations.

CONTROL: Several measures, including preventive silivculture, chemical stump treatments, and biological control have demonstrated efficacy for minimizing losses to *H. annosum* (Froelich and Nicholson 1973; Froelich *et al.* 1978; Hodges 1970; Kuhlman *et al.* 1976; Morris and Frasier 1966; Ross *et al.* 1981; Weiss *et al.* 1978). These have been variously summarized and recommended by the U.S. Forest Service (Alexander and Anderson 1985; Anderson and Mistretta 1982; Froelich *et al.* 1977; Robbins 1984: Williston *et al.* 1980). Consideration of the following general guidelines is advised.

In disease-free stands on high hazard sites, the application of appropriately registered, granular or soluble borax to fresh-cut stump surfaces during thinnings or other partial cuts may be warranted to prevent infection in residual trees. However, the cost-effectiveness of this practice is not firmly established and will be a function of a variety of factors. Although summer thinnings and harvests may reduce risks of *H. annosum* infection, summer bark beetle activity argues against this practice in Florida. Prescription burns and minimization of thinnings and other partial harvests during stand or crop-tree rotations are advisable. Longleaf pine (*P. palustris* Mill.), where silviculturally acceptable, may be worth considering as a regeneration alternative as it is a relatively resistant host species (compared to other *Pinus* spp.) On low hazard sites, preventive measures are generally not required.

Badly diseased stands may be salvaged to minimize economic losses. In stands with high public access such as recreation areas or parks, removal of diseased trees will have positive safety and liability ramifications (Slaughter and Rizzo 1999). When faced with such situations, age of the infections (e.g., time since previous harvests or tree removals) should be considered, as mortality and windthrow maximize after 4-8 years and tend to stabilize thereafter. When removing trees in diseased stands, avoid treating fresh-cut stumps with borax. Use of borax in stands already infected with *H. annosum* can make matters worse by inhibiting the action of competitive microflora. Following harvests of diseased stands, infested sites may be reforested (planted) on normal schedules, as anticipated regeneration losses generally are not sufficient to warrant delayed planting (Alexander and Anderson 1985; Froelich *et al.* 1977; Kuhlman 1986; Hodges 1970; Kuhlman *et al.* 1976; Williston *et al.* 1980).

SURVEY AND DETECTION: Look for thin-crowned, dead/dying, and/or windthrown pines, especially in stands thinned 3-6 years earlier. Dead/dying redcedars may also be good indicators. Remove the litter/duff layer(s) around stumps and suspect tree bases to reveal typical basidiomata (conks). Excavate and examine roots for resinosis, staining, resin-impregnation, and/or typical white stringy rot. In the absence of definitive basidiomata or white stringy rot, laboratory isolation is required for confirmation.

LITERATURE CITED:

Alexander, S.A., J.M. Skelly, R.S. Webb, T.R. Bardinelli and B. Bradford. 1980. Association of *Heterobasidion annosum* and the southern pine beetle on loblolly pine. Phytophathology 70: 510-513.

Alexander, S.A., J.M. Skelly, and R.S. Webb. 1981. Effects *of Heterohasidion annosum* on radial growth in southern pine beetle-infested loblolly pine. Phytopathology 71: 479-481.

Alexander, S.A., and R.L. Anderson. 1985. How to identify and control annosus root rot in the south. U.S. Department of Agriculture Forest Service, Southern Region, Forestry Bulletin R8-FB/P 19. 8 p. Alexander,

S.A., **J.M. Skelly, and C.L. Morris.** 1975. Edaphic factors associated with the incidence and severity of disease caused by *Fomes annosus* in loblolly pine plantations in Virginia. Phytopathology 65: 585-591.

Anderson, R.L., and P.A. Mistretta. 1982. Management strategies for reducing losses caused by fusiform rust. annosus root rot, and littleleaf disease. U.S. Department of Agriculture Forest Service, Cooperative State Research Service, Agriculture Handbook 597. 30 p.

Applegate, H.W. 1971. Annosus root rot mortality in once-thinned loblolly pine plantations in Tennessee. Plant Disease Reporter 55: 625-627.

Barnard, E.L., G.M. **Blakeslee, J.T.** English, S.W. **Oak, and R.L. Anderson. 1985.** Pathogenic fungi associated with sand pine root disease in Florida. Plant Disease 69: 196-199.

Barnard, E.L., S.P. Gilly, **and** W.N. **Dixon.** 1991. Incidence of *Heterobasidion annosum* and other root-infecting fungi in residual stumps and roots in thinned slash pine plantations in Florida. Plant Disease 75: 823-828.

Barnard, E.L. and J.R. Meeker. 1995. *Leptographium* root infections in pines in Florida. Florida Department of Agriculture and Consumer Services, Division of Plant Industry, Gainesville. Plant Pathology Circular No. 369. 3 p.

Boyce, J.S., Jr. 1963. Colonization of pine stem sections by *Fomes annosus* and other fungi in two slash pine stands. Plant Disease Reporter 47: 320-324.

Driver, C.H., and T.R. Dell. 1961. *Fomes annosus* causes severe damage to thinned slash pine plantation in south Georgia. Plant Disease Reporter 45: 660.

Driver, C.H., and J.H. Ginns, Jr. 1964a. The effects of climate o occurrence of annosus root rot in thinned slash pine plantations. Plant Disease Reporter 48: 509-51 I.

Driver, C.H., and J.H. Ginns, Jr. 1964b. Annosus root rot in young southern pine planted on an infested site. Plant Disease Report 48: 803-807.

Driver, C.H., and J.H. Ginns, Jr. 1969. Ecology of slash pine stumps: fungal colonization and infection by *Fomes annosus*. Forest Science 15: 2-10.

Froelich, R.C., E.B. Cowling, L.V. Collicott, and **T.R. Dell.** 1977. *Fomes annosus* reduces height and diameter growth of planted slash pine. Forest Science 23: 299-306.

Froelich, R.C., T.R. Dell, and C.H. Walkinshaw. **1966.** Soil factors associated with *Fames annosus* in the Gulf States. Forest Science 12: 356-361.

Froelich, R.C., C.S. Hodges, Jr., and S.S. Sackett. 1978. Prescribed burning reduces severity of annosus root rot in the south. Forest Science 24: 93-100.

Froelich, R.C., E.G. Kuhlman, C.S. Hodges, M.J. Weiss, and J.D. Nichols. 1977. *Fomes annosus* root rot in the South: Guidelines for prevention. USDA Forest Service, Southern Forest Experiment Station, Southeastern Forest Experiment Station, and Southeastern Area State and Private Forestry. 17 p.

Froelich, R.C., and J.D. Nicholson. 1973. Spread of *Fomes annosus* reduced by heavy application of sulfur. Forest Science 19: 75-76.

Gilbertson, R.L., and L. Ryvarden. 1986. North American polypores. Vol. I. Fungiflora. Oslo, Norway. 433 p.

Gooding, G.V., Jr. C.S. **Hodges, Jr., and E.W. Ross. 1966.** Effect of temperature on growth and survival of *Fomes annosus*. Forest Science 12: 325-333.

Hendrix, F.F., and E.G. Kuhlman. 1964. Root infection of *Pinus elliottii* by *Fomes annosus*. Nature 201: 55-56.

Hendrix, F.F., Jr., E.G. Kuhlman, C.S. Hodges, Jr., and E.W. Ross. 1964. *Fomes annosus* - a serious threat to regeneration of pine. USDA Forest Service, Research Note SE-24. 4 p.

Hodges, C.S., Jr. 1969. Modes of infection and spread of *Fomes annosus*. Annual Review of Phytopathology. 7: 247-266.

Hodges, C.S., 1970a. Evaluation of stump treatment chemicals for control of *Fomes annosus*. pp. 43-53. *In* Hodges, C.S., J. Rishbeth, and A. Yde-Anderson (eds.). *Fomes annosus*. Proceedings of the Third International Conference on *Fomes annosus* (Aarhus, Denmark July 29-August 3, 1968). IUFRO and USDA Forest Service. Washington, D.C.

Hodges, C.S., Jr. 1970b. Regeneration of pine on *Fomes* annosus-infested sites in the southeastern United States. pp 71-76. In Hodges, C.S., J. Rishbeth, and A. Yde-Anderson (eds.). *Fomes annosus*. Proceedings of the Third International Conference on *Fomes annosus* (Aarhus, Denmark July 29-August 3, 1968). 1U FRO and USDA Forest Service. Washington, D.C.

Hodges, C.S., Jr., 1974. Symptomatology and spread of *Fomes annosus* in southern pine plantations. USDA Forest Service. Research Paper SE-114. 10 p.

Hodges, C.S., and E.G. Kuhlman. 1974. Spread of *Fomes annosus* in roots of redcedar and loblolly pine. Plant Disease Reporter 58: 282-284.

Kuhlman, E.G. 1969. Number of conidia necessary for stump root infection by *Fomes annosus*. Phytopathology 59: 1168-1169.

Kuhlman, E.G. 1986. Impact of annosus root rot minimal 22 years after planting pines on root rot infested sites. Southern Journal of Applied Forestry 10: 96-98.

Kuhlman, E.G., C.S. Hodges, Jr., and R.C. Froelich. 1976. Minimizing losses to *Fomes annosus* in the southern United States. USDA Forest Service, Research Paper SE-151. 16 p.

Morris, C.L. **1970.** Volume losses from *Fomes annosus* in loblolly pine in Virginia. Journal of Forestry 68: 283-294.

Morris, C.L., and D.H. Frasier. 1966. Development of a hazard rating for *Fomes annosus* in Virginia. Plant Disease Reporter 50: 510-511.

Powers, H.R., Jr., and J.S. Boyce, Jr. 1961. *Fomes annosus* on slash pine in the southeast. Plant Disease Reporter 45306-307.

Powers, H.R.,Jr., and A.F. **Verrall.** 1962. A closer look at *Fomes annosus.* Forest Farmer 21(13): 8-9, 16-17.

Robbins, K. 1984. Annosus root rot in eastern conifers. USDA Forest Service, Forest Insect and Disease Leaflet No. 76. 10 p.

Ross, E.W. 1969. Thermal inactivation of conidia and basidiospores of *Fomes annosus.* Phytopathology 59: 1798-1801.

Ross, E.W. 1973. *Fomes annosus* in the southeastern United States: Relation of environmental and biotic factors to stump colonization and losses in the residual stand. USDA Forest Service, Technical Bulletin No. 1459. 26 p.

Ross, E.W., and C.S. Hodges, Jr. 1981. Control *of Heterobasidium annosum* colonization in mechanically sheared slash pine stumps treated with *Peniophora gigantea*. USDA Forest Service, Southern Forest Experiment Station. Research Paper SE-229. 3 p.

Slaughter, G.W., and D.M. Rizzo. 1999. Past forest management promoted root disease in Yosemite Valley. California Agriculture 53(3): 17-24.

Sinclair, W.A., H.H. Lyon, and W.T. Johnson. 1987. Diseases of trees and shrubs. Comstock Publishers, Cornell University Press. Ithaca, NY. 574 p.

Weiss, M.J., P.H. Peacher, J.L. **Knighten, and C.E. Affeltranger.** 1978. Annosa root rot stump treatment: A pilot project. USDA Forest Service, Southeastern Area, State and Private Forestry. Forestry Report SA-FR I. 22 P

Williston, H.L., T.J. Rogers, and R.L. Anderson. 1980. Forest management practices to prevent insect and disease damage to southern pine. USDA Forest Service, Southeastern Area. Forestry Report SA-FR9. 9 p.