Recovery Plan for Laurel Wilt on Redbay and Other Forest Species

Caused by *Raffaelea lauricola*, vector *Xyleborus glabratus*

December 2009

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This recovery plan is one of several disease-specific documents produced as part of the National Plant Disease Recovery System (NPDRS) called for in Homeland Security Presidential Directive Number 9 (HSPD-9). The purpose of the NPDRS is to insure that the tools, infrastructure, communication networks, and capacity required to mitigate the impact of high consequence plant disease outbreaks are such that a reasonable level of crop production is maintained.

Each disease-specific plan is intended to provide a brief primer on the disease, assess the status of critical recovery components, and identify disease management research, extension, and education needs. These documents are not intended to be stand-alone documents that address all of the many and varied aspects of plant disease outbreak and all of the decisions that must be made and actions taken to achieve effective response and recovery. They are, however, documents that will help USDA guide further efforts directed toward plant disease recovery.

Executive Summary

Laurel wilt is a destructive vascular disease of trees in the laurel family (Lauraceae). It is caused by the fungus *Raffaelea lauricola*, a symbiont of the non-native redbay ambrosia beetle (RAB), *Xyleborus glabratus*. Since 2003, laurel wilt has caused substantial, widespread mortality of redbay (*Persea borbonia*) trees in South Carolina, Georgia, and Florida and has recently been detected in Mississippi. Other native forest species such as sassafras (*Sassafras albidum*) and the endangered pondspice (*Litsea aestivalis*) and pondberry (*Lindera melissifolia*) (on state and federal endangered species lists, respectively) are also susceptible hosts of the disease, but the impact (both realized and potential) on these species is less certain. The RAB is the only known vector of the pathogen and carries spores of *R. lauricola* in special fungus-growing structures near its mouthparts. Trees become infected when female RABs initiate attacks on healthy host trees and introduce the pathogen into the xylem. The infection restricts the flow of water in the tree, induces a black discoloration in the outer sapwood and causes the leaves to wilt.

Laurel wilt is now well established in the southeastern Atlantic Coastal Plain region of the U.S. and eradication of the vector and pathogen in this region is not feasible. Continued dramatic reductions in redbay populations are anticipated, although survival of redbay regeneration in the aftermath of laurel wilt epidemics suggests that redbay will not go extinct. Although redbay and most of the other native host species are not highly important commercially from the standpoint of wood utilization, fruit production, or ornamental trade, laurel wilt does cause economic, ecological and aesthetic impacts that have not been well quantified. In many forests and other natural areas with a redbay component, the most reasonable management response where laurel wilt is established may be to simply let the disease run its course. "Recovery" from laurel wilt in redbay and other forest species could be considered in terms of the following general courses of action:

- Slow the long distance, human-assisted spread of the disease.
- Improve our understanding of the biology, host associations, and impacts of the disease and its vector.
- Protect individual, high-value landscape trees with pesticides when feasible.
- Develop other tools for management of the disease and its vector, possibly to include sanitation, other silvicultural methods, trap-out or attract-and-kill techniques, use of resistant genotypes, and biological control.
- Assess the need for, and possibly pursue, a germplasm conservation program for threatened hosts.
- Continue to monitor the geographic spread of the disease, assess its impacts on host species as its spreads to new ecosystems, and educate the public about the issue.

Individuals from a variety of government agencies, colleges and universities, non-profit organizations, private companies, and other entities are working collaboratively to understand and address the presence of laurel wilt in the U.S. These collaborative relationships and the sharing of information should continue.

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Recovery Plan for
Laurel Wilt on Redbay and Other Forest Species
Caused by *Raffaelea lauricola*,
vector *Xyleborus glabratus*

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I. Introduction

Laurel wilt is a destructive vascular disease of trees in the laurel family (Lauraceae). The disease is caused by the fungus *Raffaelea lauricola* T.C. Harr., Fraedrich & Aghayeva, a symbiont of the redbay ambrosia beetle (RAB), *Xyleborus glabratus* Eichhoff (Coleoptera: Curculionidae: Scolytinae). This disease was unknown prior to 2003, and the pathogen has just recently been named and described (Harrington et al. 2008). The RAB is not native to North America and the first U.S. record was collected from a survey trap near Port Wentworth, Georgia in 2002 (Rabaglia et al. 2006). Female RABs carry spores of the laurel wilt fungus in special sacs near their mouthparts and are the primary vector. Since 2003, laurel wilt has caused substantial, widespread mortality of redbay (*Persea borbonia* (L.) Spreng.) in South Carolina, Georgia, and Florida (Fraedrich et al. 2008) and has recently been detected in Mississippi (J. Riggins et al., unpublished).

The RAB is native to Asia and has been reported from India, Bangladesh, Japan, Myanmar and Taiwan (Rabaglia et al. 2006). Reported host plants in the Asian range include species in the families Lauraceae (*Lindera latifolia* Hook. f., *Litsaea elongata* (Nees) Benth. et Hook. f. and *Phoebe lanceolata* (Wall. ex Nees) Nees), Dipterocarpaceae (*Shorea robusta* C. F. Gaertn), Fagaceae (*Lithocarpus edulis* (Makino) Nakai), and Fabaceae (*Leucaena glauca* (L.) Benth.) (Rabaglia et al. 2006). Laurel wilt disease, however, is not known to occur in these or other species in the RAB's native range. The laurel wilt fungus (*Raffaelea lauricola*) is presumed to have arrived in North America with the RAB via importation of solid wood packing material (Harrington et al. 2008).

In North America, laurel wilt has only been observed in woody plants of the family Lauraceae. The laurel wilt pathogen has been recovered from diseased plants of the following species in the field:

- Redbay, *Persea borbonia* (L.) Spreng. (Fraedrich et al. 2008)
- Swampbay, *Persea palustris* (Raf.) Sarg. (Fraedrich et al. 2008)
- Avocado, *Persea americana* Mill. (Mayfield et al. 2008b)
- Sassafras, *Sassafras albidum* (Nutt.) Nees (Fraedrich et al. 2008, Smith et al. 2009a)
- Pondspice, *Litsea aestivalis* (L.) Fernald (Fraedrich et al. 2008)
- Pondberry, *Lindera melissifolia* (Walter) Blume (Fraedrich et al. 2008)
- Camphor, *Cinnamomum camphora* (L.) J. Presl (Smith et al. 2009b)

Redbay and swampbay are broadleaved, evergreen, typically small to medium-sized trees limited to the southeastern Atlantic Coastal Plain region of the U.S. Some taxonomists do not consider redbay and swampbay distinct species, and these species in combination with silkbay (*Persea borbonia* (L.) Spreng. var. *humilis* (Nash) L.E. Kopp) are sometimes referred to collectively as "redbay." Laurel wilt is devastating to redbay (*sensu lato*) in all habitats where the host and vector occur and has caused mortality in excess of 90% of stems greater than 1 inch diameter within 2 years in some stands (Fraedrich et al. 2008). Smaller diameter redbay seedlings and sprouts appear to be much less frequently affected by the disease in the field (Fraedrich et al. 2008). Laurel wilt has killed avocado yard trees and experimentally planted avocados in coastal Florida (Mayfield et al. 2008b), and a separate Recovery Plan for this disease on avocado is being prepared. Although the known incidence of laurel wilt in sassafras has been limited to coastal plain regions of South Carolina, Georgia, and Florida, sassafras is distributed throughout the eastern United States. Laurel wilt on sassafras has been observed in geographic isolation from diseased redbays, both in individual trees as well as thickets of multiple ramets originating from a common root system (Smith et al. 2009a). RAB has been observed breeding in sassafras, but it is still unclear whether laurel wilt will spread through sassafras into the Piedmont region and out of the range of redbay. A few occurrences of laurel wilt have been detected on pondspice and pondberry, which are recognized as endangered species at the state and federal levels, respectively (http://plants.usda.gov). Laurel wilt has also occurred in Florida and Georgia in camphor, a non-native invasive species of Asian origin, but widespread mortality in camphor has not been observed and there may be some level of resistance to the pathogen in this host (Smith et al. 2009b).

Numerous other plant species native to the United States have been tested for susceptibility to the laurel wilt pathogen in artificial inoculation trials. Those on which *Raffaelea lauricola* appears to be pathogenic, but have not been confirmed as hosts in the field, include northern spicebush (*Lindera benzoin* (L.) Blume) and California laurel (*Umbellularia californica* (Hook. & Arn.) Nutt.) (Fraedrich et al. 2008, Fraedrich 2008). Furthermore, pondspice, pondberry, lancewood (*Ocotea coriaceae* (Sw.) Britton) and eastern sweetshrub (*Calycanthus floridus* L.) all show susceptibility to laurel wilt to varying degrees in controlled inoculation studies (S.W. Fraedrich, unpublished).

Although there could potentially be a large number of plant species that are found to be susceptible to the laurel wilt pathogen when artificially inoculated, it should be noted that some may be at relatively low risk of damage from laurel wilt disease if they 1) are not attractive to the RAB, 2) do not serve as suitable breeding material for the RAB, and/or 3) are geographically isolated from host species in which RAB populations can reproduce readily (e.g., redbay).

II. Disease Cycle and Symptoms

A suggested disease cycle for laurel wilt in redbay is presented in Figure 1. Dispersing female RABs fly and initiate attacks on the main stem or branches of healthy redbay trees. These early attacks on healthy trees may be initiated by only one or very few beetles and apparently do not result in successful construction of galleries and brood production in the host (Fraedrich et al. 2008). However, these aborted attacks may be sufficient to inoculate the host sapwood with spores of *Raffaelea lauricola*, which bud in a yeast phase in specialized pouches (mycangia) near the beetle’s mouthparts (Fraedrich et al. 2008, Harrington et al. 2008). The pathogen moves systemically in the sapwood of the tree and presumably causes a restriction in the flow of water and the leaves to wilt. The drooping foliage takes on a reddish or purplish discoloration and may be limited to portions of the crown initially (Fig. 2). In redbay, the entire crown eventually wilts and turns brown (Fig. 3) over a period that may take from a few weeks to 2-3 months. Wilted leaves may remain attached to redbay trees for up to a year or more. Removal of bark from wilted trees reveals a dark black discoloration in the outer sapwood, running with the grain of the wood (Fig. 4). Although sapwood discoloration is a general symptom that can occur for other reasons, this is the most diagnostic symptom of laurel wilt in the field. The vascular discoloration may occur as localized streaks early in disease process, but it develops more extensively in the outer sapwood throughout the tree by the time wilt symptoms occur (Fraedrich et al. 2008).

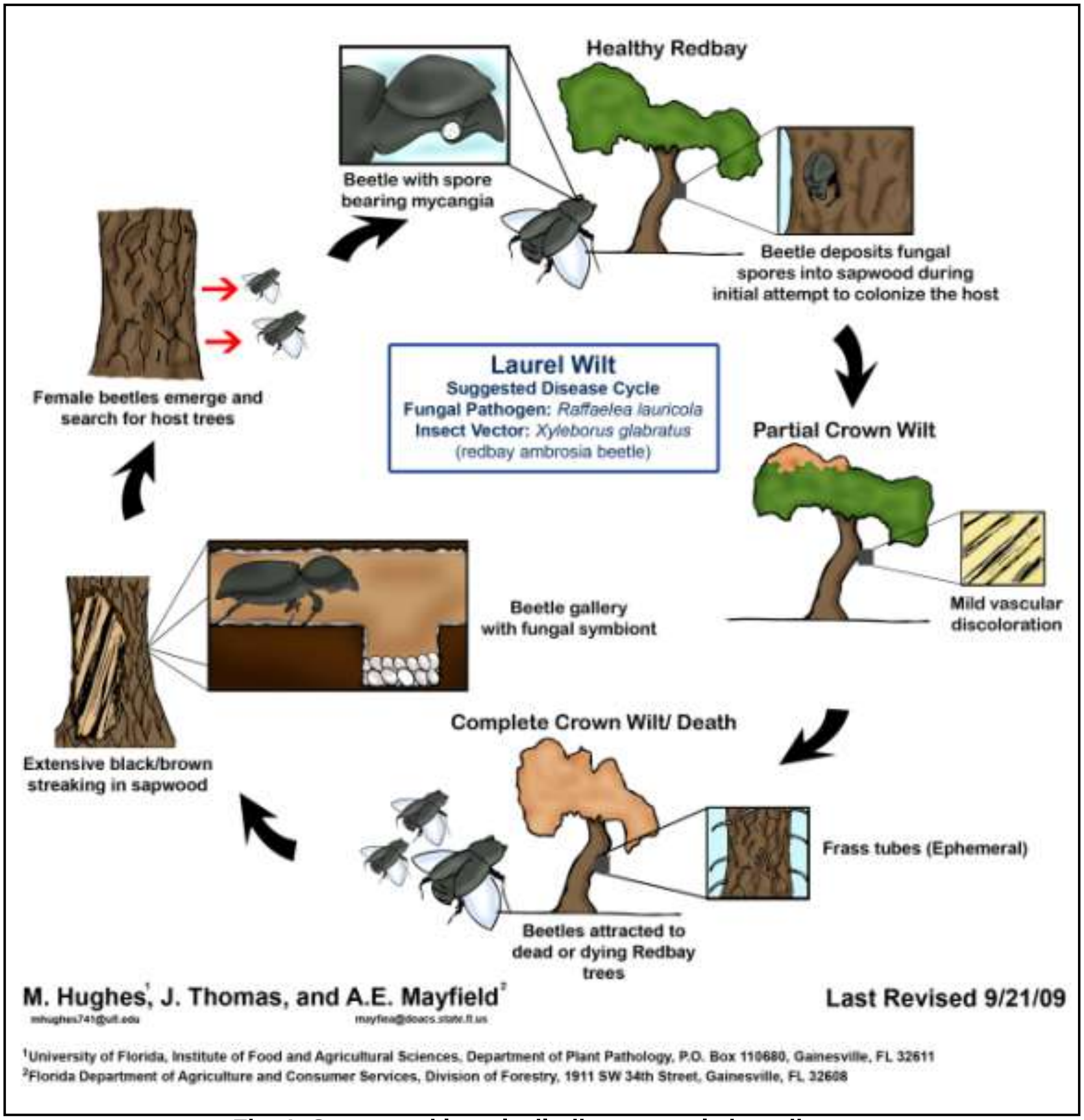

Fig. 1. Suggested laurel wilt disease cycle in redbay.

Fig. 2. Drooping and discolored foliage of redbay trees in the early stages of laurel wilt. Photos by A.E. Mayfield III, Florida DACS Division of Forestry.

Fig. 3. Brown leaves retained in the crown of redbay trees killed by laurel wilt. Photos by A.E. Mayfield III, Florida DACS Division of Forestry.

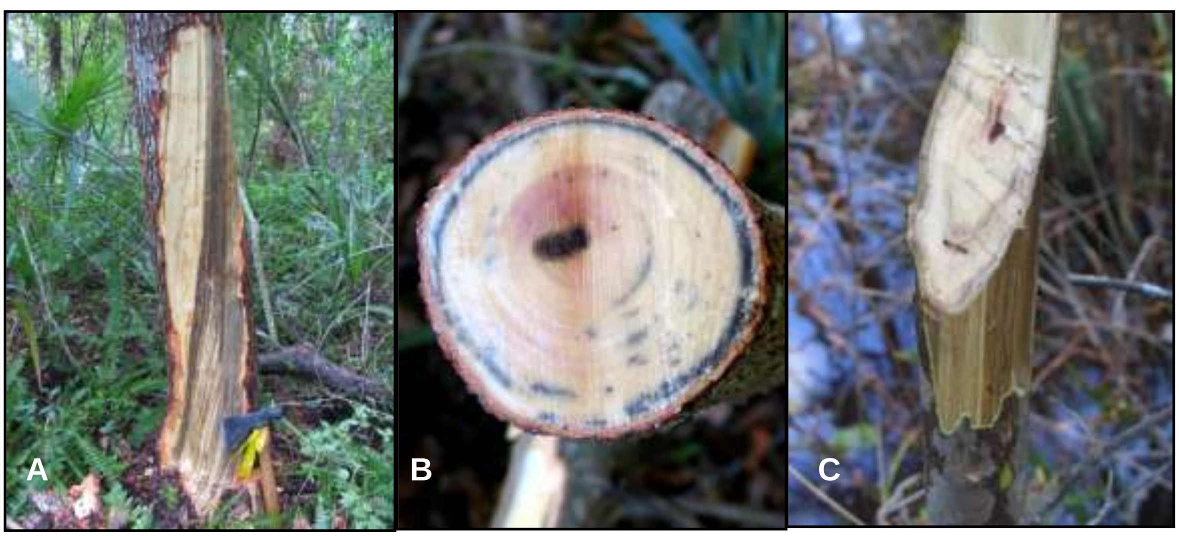

Fig. 4. Black discoloration in the outer sapwood of redbay (A,B) and pondspice (C) with laurel wilt. Photos by A.E. Mayfield III, Florida DACS Division of Forestry.

After a redbay tree has died, it is typically attacked by additional RABs and other species of ambrosia beetles that breed in the dead sapwood. At this stage, the bark may exhibit boring dust, either in piles or as dowel- or toothpick-like structures composed of compacted dust that protrude from the stem (Fig. 5). However, this boring dust on the outer bark is ephemeral and not always evident, and it can be produced by ambrosia beetles other than the RAB. The RAB creates galleries in the sapwood where it lays eggs and cultivates symbiont fungi on which it feeds. Female RABs are able to produce flightless male offspring without mating, but females may mate with their male offspring or sibling males to produce males and females. Females greatly outnumber males in RAB populations. In the Southeast, the RAB life cycle from egg to adult appears to take 50-60 days, and there appear to be multiple overlapping generations per year (Hanula et al. 2008, J.L. Hanula, unpublished). Female RABs emerging from a dead redbay may reinfest the same tree or disperse in search of new hosts. Dead redbay trees can remain standing for years and may continue to serve as host material for the RAB for several months after initial colonization. Many coastal forests have hundreds of redbay trees per acre allowing RAB populations to build rapidly.

Fig. 5. Dowels of ambrosia beetle boring dust protruding from a redbay killed by laurel wilt. This symptom is not always observable and can be produced by ambrosia beetle species other than the redbay ambrosia beetle. Photo by A.E. Mayfield III, Florida DACS Division of Forestry.

The female RAB (Fig. 6, A-C) is an extremely small (2.1 - 2.4 mm long), cylindrical, black to dark brown beetle with a relatively smooth (glabrous) surface and an elytral declivity (rear slope of wing covers) that is steeply sloping, convex, and subacutely pointed (Rabaglia et al. 2006). The males are similar to females but are smaller, slightly deformed, haploid, flightless, highly outnumbered by females, and rarely leave the galleries within the host tree (Fig. 6, D-E). The laurel wilt pathogen (*Raffaelea lauricola*) (Fig. 7) lives as a budding, yeast-like phase within the mycangium of the RAB. In culture, the fungus forms colonies that are initially mucilaginous, with hyphae eventually growing from the margins and producing yeast-like conidia from small conidiophores (Harrington et al. 2008).

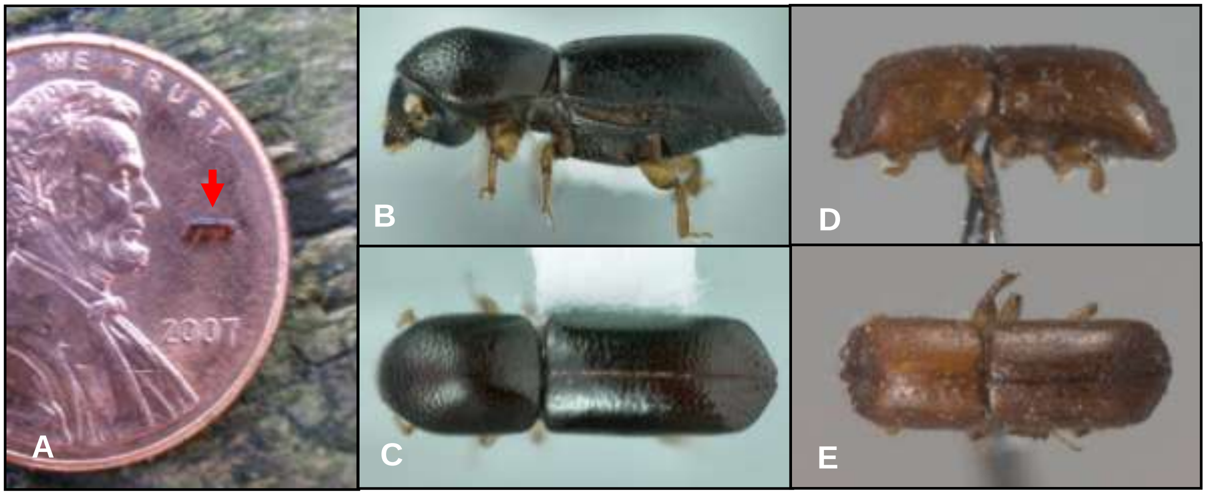

Fig. 6. A female redbay ambrosia beetle, *Xyleborus glabratus* (length ~2 mm) on the head of a penny (A); lateral closeup, female (B); dorsal closeup, female (C), lateral closeup, male (D); dorsal closeup, male (E). Photos by A.E. Mayfield III, Florida DACS Division of Forestry (A), Florida DACS Division of Plant Industry (B,C), and J. Hanula, USDA Forest Service (D,E).

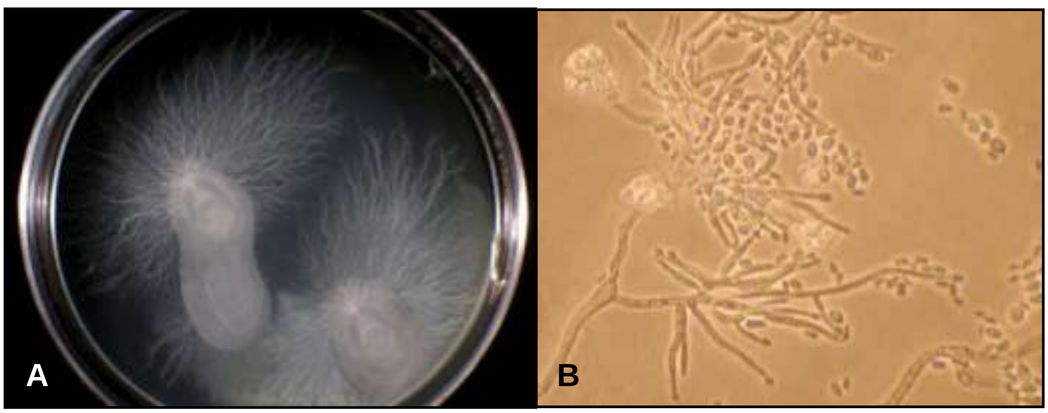

Fig. 7. Colonies of *Raffaelea lauricola* growing from diseased wood chips in culture (A), and conidia and conidiophores under magnification (B). Photos by T.S. Schubert, Florida DACS Division of Plant Industry (A) and S.W. Freadrich, USDA Forest Service (B).

Laurel wilt symptom expression in some other host species may vary somewhat from those observed in redbay. In avocado and sassafras, wilted leaves do not remain attached to the host for an extended period of time as in redbay. The vascular discoloration can vary and may appear brownish or bluish in some individual plants or species. In camphor, infections with the laurel wilt pathogen may result only in isolated branch flagging or dieback, from which the tree may recover (Cameron et al. 2008).

The black twig borer (*Xylosandrus compactus* (Eichhoff)) can cause damage that is commonly misdiagnosed as early symptoms of laurel wilt. The black twig borer is a small ambrosia beetle that attacks small diameter twigs of healthy trees of a large number of host species and is very common on redbay. The female black twig borer produces a tiny entrance hole (0.8 mm) on the underside of a twig, creates a brood chamber in the pith, and cultivates its symbiotic ambrosial fungus therein (Dixon and Woodruff 1982). The twig may also display dark discoloration in the wood around the entrance hole and brood chamber. These attacks cause death and "flagging" of the isolated infested twigs, which may retain their brown leaves, but the black twig borer does not kill large branches or entire sections of the crown as does laurel wilt. Isolated or scattered branch flagging characterized by tiny pinholes in the twigs and no progression in severity over a matter of a few weeks can commonly be attributed to black twig borer (Fig 8).

Fig. 8. The black twig borer (*Xylosandrus compactus*) creates pinholes in small diameter twigs (A) and causes isolated branch flagging (B) on redbay that can be incorrectly diagnosed as early stages of laurel wilt. Photos by A.E. Mayfield III, Florida DACS Division of Forestry.

III. Spread

The geographic range of laurel wilt has expanded rapidly since the recognition of the disease in three counties in 2004 (Chatham County, GA and Beaufort and Jasper Counties, SC). In the following 5 years, the disease has been detected in at least 60 counties in four southeastern states (Fig. 9). The RAB is the only confirmed vector of the laurel wilt pathogen at this time. As described above, natural spread of the pathogen occurs as female beetles exit and fly from diseased trees and initiate attacks on other host plants. The spread of laurel wilt through a network of barrier islands in Georgia (Cameron et al. 2008) suggests that RABs are capable of dispersing naturally at least a few kilometers. Given the extremely small size of RAB, it is possible (though undocumented with this beetle) that strong air currents or storms could carry the beetles much greater distances than they are capable of flying unassisted. Because the RAB can reproduce without mating, potentially only one female beetle is needed to start a population in a new, isolated location if it finds suitable host material.

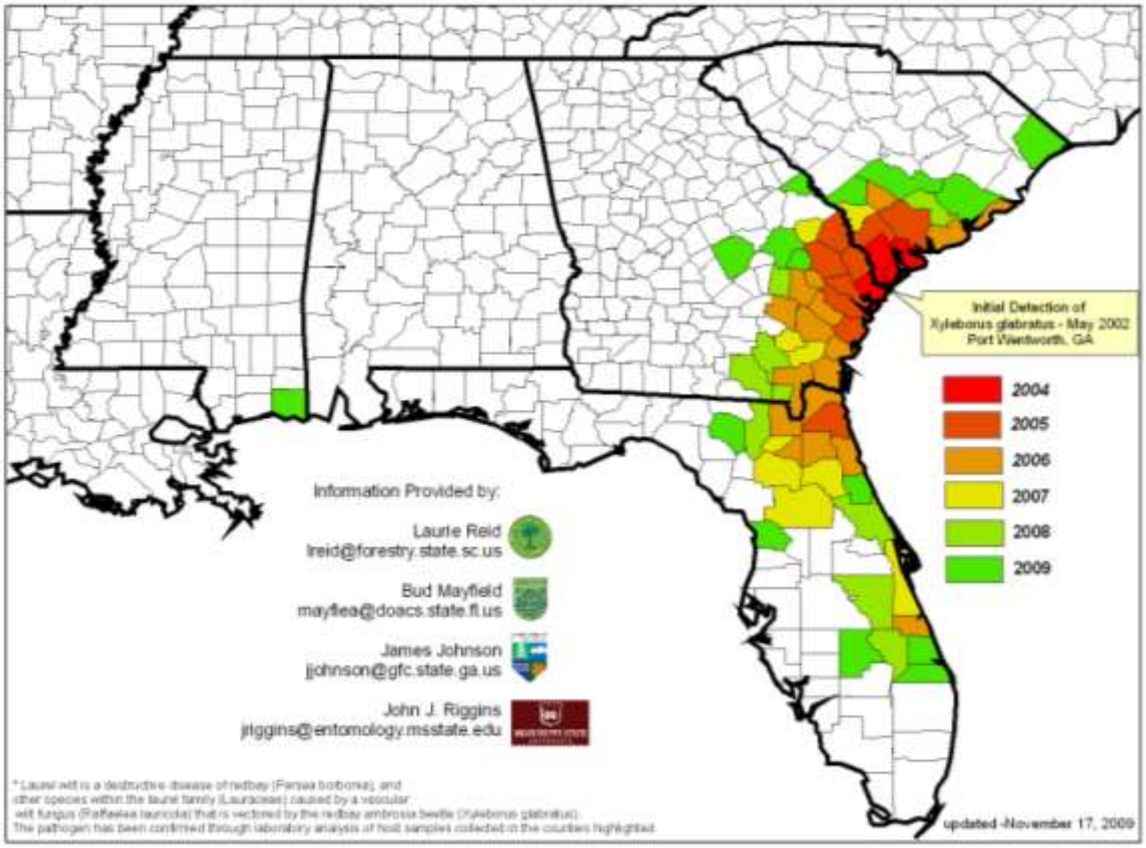

Fig. 9. Distribution of counties with laurel wilt disease, by year of initial detection, 2004-2009.
Available online at: http://www.fs.fed.us/r8/foresthealth/laurelwilt/index.shtml

The detection of laurel wilt in locations widely separated from the known leading edge of the disease range strongly suggest that human transport of infested wood is contributing to the long-distance spread of the pathogen and vector. The vector and disease were first detected near the ports of Savannah, Georgia where unloaded ships provide abundant solid wood packing material, a common introduction pathway for non-native ambrosia beetles (Haack 2006). Other instances specific to the RAB include the detection of laurel wilt in Indian River County, FL (in 2006) and in Jackson County, MS (in 2009), locations that were more than 200 km and 400 km, respectively, from the nearest known incidences of the disease. Other isolated occurrences of laurel wilt in Georgia were associated with a hardwood mulch plant and a state park, into which infested firewood could have been transported (Cameron et al. 2008). A localized outbreak of the disease was also detected near the shop of a woodturner who collected redbay logs from an infested area in Florida. Thus, the suspected pathways of long distance spread include human transport of infested solid wood packing material, firewood, logs, and chipped host material for pulping or landscape mulch.

Pathogen spread via root grafting occurs with other similar vascular tree diseases such as oak wilt and Dutch elm disease, but this has yet to be conclusively demonstrated as a means of spread of the laurel wilt pathogen. Vascular discoloration can be observed extending down into the root systems of diseased redbays, sassafras and avocado. Cameron et al. (2008) noted the rapid movement of laurel wilt through a clump of sassafras, which commonly produces genetically identical ramets originating from a common root system. The lack of evidence of ambrosia beetle attack upon cursory inspection of those sassafras ramets suggested that the pathogen may have moved from sprout to sprout through the root system, a possibility worthy of further investigation.

Koch and Smith (2008) used existing laurel wilt survey data, redbay and sassafras distribution inventories, and a climate-matching procedure to predict the rate of spread and potential geographic limits of the RAB in the eastern U.S. They suggest that based on climate similarity of the beetle's native range in Asia, the RAB may be constrained to the southeastern Atlantic Coastal Plain (roughly coincident with the native range of redbay) and that unchecked spread of laurel wilt through this range will take less than 40 years. Thus far, laurel wilt has remained in the Atlantic Coastal Plain region and appears to have spread more rapidly to the south and west than it has north along the Atlantic coast (Fig. 9). The recent detection of laurel wilt in Mississippi was many years ahead of the time frame predicted by Koch and Smith's (2008) spread model, and the extent of the redbay mortality in Mississippi would suggest that the pathogen and vector had already been present in that area for at least 1-2 years. It is likely that field detections of laurel wilt will lag behind arrival of the pathogen and vector in many instances, given the often "low profile" nature of redbay as a non-commercial, midstory forest species. It remains to be seen whether the RAB and the laurel wilt pathogen will successfully establish and spread into other regions of the U.S. through utilization of other more widely distributed lauraceous species like sassafras or northern spicebush. Although RAB is known to successfully breed in sassafras, Hanula et al. (2008) did not find the RAB to be attracted to cut stems of sassafras and speculated that this might slow the spread of laurel wilt out of the southeastern Atlantic Coastal Plain. Current observations of laurel wilt on sassafras indicate that the disease continues to move into the interior counties of Georgia, including areas where redbay is neither a major component of the forest and in some cases is not in the immediate vicinity. Long-term monitoring of sassafras on plots in Georgia (outside of the range where redbay occurs) should help answer questions about the dynamics of this disease is sassafras.

IV. Monitoring and Detection

Survey and monitoring of laurel wilt has primarily been coordinated at the state level with funding and cooperative assistance from federal agencies. The Georgia Forestry Commission (Cameron et al. 2008) and South Carolina Forestry Commission (Boone 2008) have conducted or contracted ground surveys with funding from the USDA Forest Service Forest Health Protection for incidence and impact of laurel wilt using systematic plot sampling. Monitoring of the spread of laurel wilt in Florida has been maintained by field detections and reports from state Division of Forestry personnel, University of Florida county extension agents, state Division of Plant Industry inspectors, and others familiar with the disease symptoms as a result of education and outreach. The Florida Cooperative Agricultural Pest Survey (CAPS) Program has conducted laurel wilt surveys targeting south Florida redbay stands and avocado orchards, using both field inspections for host symptoms and monitoring of Lindgren funnel traps baited with manuka oil (Griffiths et al. 2009). All states affected by the disease have taken efforts to educate the public and train natural resource field personnel in field recognition of laurel wilt and collection of sample material, and they have contributed to the multi-state, county-level laurel wilt distribution map (Fig. 9).

Unlike most ambrosia beetles, the RAB is weakly or not attracted to ethanol-baited traps (J.L. Hanula, unpublished). Early efforts to monitor for the vector utilized cut redbay stems (to which RAB is readily attracted) suspended from Lindgren funnel or other flight intercept traps, but this is not ideal in that host material is not always available for cutting in areas targeted for monitoring. Hanula and Sullivan (2008) found that manuka oil and phoebe oil are attractive to the RAB, and the commercial availability of lures of these oils have improved the ability of agencies to monitor for the vector.

A detailed Standard Operating Procedure (SOP available by contacting Carrie Harmon at clharmon@ufl.edu) for plant diagnostic laboratories has been created for laurel wilt through the National Plant Diagnostic Network (NPDN) (Harmon and Brown 2009). The SOP contains information regarding diagnosis of laurel wilt via field symptoms, isolation and morphological identification of the pathogen, and molecular identification of the pathogen. The pathogen can be isolated by surface sterilization of infected xylem tissue and plating on selective media such as cycloheximide-streptomycin malt agar (Fraedrich et al. 2008). Detailed morphological descriptions of *Raffaelea lauricola* have been published (Harrington et al. 2008) and identification of the pathogen on this basis has been an adequate means of confirming the disease in symptomatic redbay, sassafras and other hosts. Molecular confirmation of *Raffaelea lauricola* has been performed via amplification and sequencing of ribosomal DNA using polymerase chain reaction (PCR) (Fraedrich et al. 2008; Harrington et al. 2008; Smith et al. 2009a). Research to find PCR primers that reliably distinguish *Raffaelea lauricola* from other fungi is currently being conducted.

V. Response

While this plan is focused primarily on recovery, there is a continuum of activities associated with the detection of a new pathogen such as *R. lauricola* and its vector. The response to all plant health emergencies is under the authority of USDA-APHIS-Plant Protection and Quarantine (USDA-APHIS-PPQ) delegated from the Secretary of Agriculture under the Plant Protection Act of 2000.

In 2002, as part of the USDA Forest Service Early Detection & Rapid Response Pilot Project, three specimens of the RAB were captured in detection traps near Port Wentworth, Georgia. This was the first record of this Asian species in North America. Later in 2002, in coordination with APHIS, additional traps were placed in the Port Wentworth area to delimit a possible establishment, but no further catches of this beetle were made. Due to the small number of beetles collected and the location of the traps near warehouses, it was thought likely that the beetles had come directly from solid-wood packing materials and had not become established in native vegetation.

In 2003, significant redbay mortality on Hilton Head Island, South Carolina was reported to the South Carolina Forestry Commission (SCFC). Much speculation ensued about the possible causes of redbay decline and mortality, including drought and water table fluctuation. In late

2004, an investigation by USDA Forest Service Southern Research Station staff eventually found the RAB and an unknown wilt fungus in redbay trees on Hilton Head. After initial inoculation experiments, the combination of the fungus and beetle was suspected to be the primary cause of redbay death.

In 2004, the Georgia Forestry Commission (GFC) was also receiving reports of redbay mortality in coastal areas. A multi-disciplinary team from the USDA Forest Service, SCFC, GFC, Florida Division of Forestry, Iowa State University, and other agencies and organizations began to cooperatively evaluate the problem and its causes. In early 2005, the wilt fungus was tentatively identified as a species of *Ophiostoma*, and was further identified as an unknown *Raffaelea* species (*Raffaelea* is an asexual genus of ambrosia beetle symbionts related to *Ophiostoma* species). Growth chamber inoculations by USDA Forest Service researchers showed the fungus to be a highly virulent wilting agent in several *Persea* species and other members of the Lauraceae family (e.g., sassafras, pondberry). The fungus was also isolated from the RAB, indicating that the beetle was a vector of the fungus.

Based on Forest Service-supported surveys, the extent of establishment of laurel wilt in 2005 was so extensive that eradication was deemed unfeasible. In 2006, lab and field studies indicated that sassafras, avocado, and two rare plant species (*Lindera melissifolia* and *Litsea aestivalis*) were susceptible to attack by the RAB and the laurel wilt fungus, although the rates of mortality for these species seemed to be lower than that for redbay.

In early 2007, a symposium was held to share what was known about the beetle and fungus and to strategize the forest health community's next steps (available at http://www.fs.fed.us/r8/foresthealth/laurelwilt/index.shtml). Interest was expressed in continued surveys and research into insecticide and fungicide use, host-range studies, pathogen-vector relationships, sanitation, ecological response, and other miscellaneous projects. A Laurel Wilt Working Group was formed to strategize/prioritize the next steps, educate the public and land managers about the issue, and coordinate efforts among interested agencies, organizations, and individuals.

A second symposium was held in early 2009 in conjunction with the national Forest Health Monitoring annual meeting. The threat to Florida's avocado industry was also a major source of discussion. Other topics included redbay resistance research, the effects of laurel wilt on plant communities, host plant susceptibility, management via chemical control, redbay seed/genetic conservation efforts, pathways and possible regulations, RAB biology, host chemistry and attraction, pathogen-vector relationships, and the laurel wilt website hosted by the USDA Forest Service.

VI. USDA Pathogen Permits

USDA-APHIS-PPQ permit and registration requirements for plant diseases and laboratories fall under the Plant Protection Act (7 CFR Part 330). The Plant Protection Act permit requirements apply to all plant pests and infected plant material, including diagnostic samples, regardless of their quarantine status, that are shipped interstate and also requires that the receiving laboratory have a permit: http://www.aphis.usda.gov/ppq/permits/ or contact PPQ permit services at (301) 734-8758. This procedure may limit early detection of laurel wilt since it complicates sending and receiving samples for identification (confirmation), although there are diagnostic laboratories in every state and all NPDN laboratories have APHIS permits to handle 'unknown' diagnostic samples. Concerted efforts to educate first detectors will insure the proper handling and identification of potential laurel wilt materials in the event that a suspect high consequence or quarantined sample is found.

VII. Economic Impact and Compensation

Potential Economic Impacts

Arguably, the greatest immediate threat of economic impact associated with the establishment and spread of laurel wilt disease in the U.S. is that posed to the commercial avocado industry, an issue to be addressed in a separate Recovery Plan. Although redbay and most of the other native host species are not highly important commercially from the standpoint of wood utilization, fruit production, or ornamental trade, laurel wilt causes economic, ecological and aesthetic impacts that have not been well quantified. Economic impacts associated with laurel wilt on redbay and other native host species may include:

- Costs to homeowners, municipalities, parks, utility companies, etc., associated with the removal and disposal of dead host trees from landscapes and along streets and rights-of-way.
- Decreased property values associated with the death or removal of large redbay trees from residential landscapes and along streets.
- Increased administrative costs to government agencies associated with providing information and educational materials to the public during a laurel wilt epidemic.
- Lost revenue to nurseries that sell redbay or other lauraceous plants due to:
    - Quarantines or stop-sales placed on the nurseries if host plants are found to harbor the laurel wilt vector or the pathogen within the nursery.
    - Decreased sales of native plants known to be susceptible to laurel wilt.
- Lost revenue or increased administrative costs to businesses that sell firewood, mulch, or other unprocessed wood products, as regulations or restrictions on the movement of unprocessed wood are enacted at federal, state, or local levels in response to the RAB and other non-native wood inhabiting pests.
- Fire hazard associated with the massive amount of redbay mortality in forests where redbay is a common midstory component. This hazard has the potential to lead to economic impacts.

Potential Ecological Impacts

Laurel wilt is devastating to redbay trees and kills nearly all mature redbay stems in impacted stands within 3-5 years. Small size classes (<1 inch diameter) of redbay regeneration appear to be generally less affected, and such regeneration has been observed in abundance in areas where virtually all the overstory and midstory redbay trees have otherwise been eliminated by laurel wilt (Cameron et al. 2008, Fraedrich et al. 2008). An explanation for the survival of this regeneration is still uncertain, but it may be that smaller redbay trees are relatively less apparent or attractive to the RAB. While the presence of redbay regeneration and the occasional discovery of live, larger-diameter saplings in the aftermath of a laurel wilt epidemic suggest that redbay will not go extinct, populations of mature redbay are nonetheless being dramatically reduced. Hanula et al. (2008) found that RAB populations dropped dramatically, but did not completely disappear, after most suitable redbay host material had been eliminated. Low-level populations of RAB were still present in 2009 in the areas where laurel wilt was first discovered and almost all suitable redbay trees for RAB brood had been eliminated at least 3 years before (J.L. Hanula, unpublished). It is not yet clear whether redbay regeneration will be able to eventually grow into mature canopy trees in such areas, or whether RAB populations will persist at low levels and continue to attack and inoculate trees with the laurel wilt pathogen once the trees reach a certain size. If low level RAB populations can be maintained in dead or weakened stems of other tree species that are not hosts for laurel wilt, then the beetle and pathogen may persist indefinitely.

To date, the ecological impacts of drastic reductions in redbay populations are not well researched or have not yet been reported in the scientific literature. Redbay produces blue drupes in the fall, and its fruit, seed and/or foliage are eaten by several species of songbirds, wild turkeys, quail, deer, and black bear (Brendemuehl 1990). Leaves of *Persea* species are the primary larval food source of the Palamedes swallowtail butterfly (*Papilio palamedes* (Drury)) (Hall and Butler 2007) and the only known hosts of the redbay psyllid (*Trioza magnoliae* (Ashmead)) (Hall 2009). Redbay (*sensu lato,* including swampbay) occurs in a very wide variety of habitats and forest types, and although not typically known as a large tree, it can reach sizes in excess of 70 feet tall and 40 inches diameter. A better understanding of the potential impacts of the local reduction or elimination of redbay on trophic, habitat or other ecological relationships is needed.

Potential ecological impacts on host species other than redbay are even less certain at this time. In a survey of more than 180 wetlands in northeast Florida, Surdick and Jenkins (2009) observed pondspice populations at 15 locations and documented varying percentages of pondspice with laurel wilt symptoms (up to 90%), but they confirmed the presence of the laurel wilt pathogen from only one site. The threat posed by laurel wilt to extirpate pondspice and pondberry populations is still unclear and deserves additional research attention. Furthermore, there are numerous other species in the Lauraceae, both in the United States (including California) and in other parts of the Western Hemisphere (including the Carribean, Mexico, Central and South America) that could be affected by laurel wilt should the vector become established within their ranges.

VIII. Mitigation and Disease Management

Laurel wilt is well established, spreading rapidly, and killing redbay trees in large numbers within a geographic area that now encompasses roughly 60,000 square miles in Florida, Georgia and South Carolina, plus an outlying area in Mississippi. Eradication of the pathogen and the vector from the southeastern Atlantic Coast is not feasible. The following realities (and perhaps others) all suggest that high levels of host mortality due to laurel wilt will continue to occur through most of the redbay range, even under the best management efforts: the extreme virulence of the pathogen in redbay, the rapid speed at which it kills individual trees and spreads through a stand, the efficiency of the vector in finding and inoculating healthy hosts, the ability of one female beetle to initiate a new population of RAB without mating, the apparent lag time between arrival of the vector and detection of the disease in a new area, and the widespread distribution of redbay in a variety of habitats in the southeastern Atlantic Coastal Plain. A number of possible management strategies for dealing with laurel wilt in redbay and other forest species are discussed below:

Limit transport of infested/infected host material

Efforts to prevent the long-distance, human-assisted spread of the RAB and laurel wilt pathogen could help delay the onset of laurel wilt impacts in currently unaffected areas, possibly allowing more time for new management tactics to be developed. Limitations on long-distance dispersal could include:

- Restrict the transport of firewood, logs, mulch, and other unprocessed wood of redbay or other known hosts, out of counties (or other designated areas) in which laurel wilt is known to occur.
- Dispose of wood from killed redbays and other lauraceous hosts as locally as possible.
- Although movement of nursery plants is not yet a documented pathway by which laurel wilt has spread, periodically inspect field or container nurseries that sell lauraceous plants for laurel wilt symptoms and RAB infestations, particularly in areas where laurel wilt is known to occur. Shipment of stock from nurseries with the RAB would only be a problem if the beetle were in or on the nursery stock. Consider adopting an insect/disease-free certification program for lauraceous plants in nurseries prior to shipment. If the movement of infested nursery stock becomes a documented pathway of RAB, consider limiting the movement of nursery plants of known host species out of designated areas in which laurel wilt occurs.

Do nothing

In many forests and other natural areas with a redbay component, the most reasonable management response after laurel wilt is established may be to simply let the disease run its course.

Sanitation

As yet, there are no proven silvicultural or arboricultural treatments for mitigating the impact of laurel wilt. One attempt to eradicate the vector and pathogen from a local area through sanitation removal/destruction of RAB-infested trees was not successful. When laurel wilt was first detected on Jekyll Island, GA in 2006, the Georgia Forestry Commission (GFC) with cooperation from the Jekyll Island Authority deployed a chainsaw strike team and removed all known symptomatic redbays (more than 400 trees) from residential and natural areas and burned them at a central location. Nonetheless, by late 2007 laurel wilt was found throughout the island (James Johnson, GFC, unpublished presentation). This underfunded eradication attempt suggests that sanitation removal of only symptomatic host material is not an effective means of mitigating the impacts of laurel wilt during an epidemic. The tactic might be more fruitful if all host trees large enough for brood production by RAB are removed, if the sanitation is augmented by protection of individual trees with pesticides (see below), and/or if applied at a time when RAB populations, disease incidence, and host abundance in the landscape are very low. A solid commitment of funds and personnel to do follow-up surveys and complete removal of brood material in a timely fashion would be necessary for long-term success with sanitation. In addition, sanitation might be used to in conjunction with mass trapping (see below) to reduce RAB populations in defined areas. At the time of the Jekyll Island trial an effective lure had not been developed.

Although eradication attempts in the currently-infested areas of the southeastern Atlantic Coastal Plain appear fruitless, spread of the vector and pathogen into new areas might be slowed by prevention of long-distance spread by human activities, and possibly by rigorous, sanitation programs aimed at suppressing laurel wilt at outlier locations. Such sanitation efforts at or beyond the leading edge of the known laurel wilt range, however, would probably only be successful where host trees are relatively scattered and could be surveyed repeatedly throughout the year, where the disease and vector have not been present for very long, and where there is a full, long-term commitment (both financially and administratively) of involved agencies and stakeholders.

Although the pathogen has not been documented to spread by any means other than the beetle vector, arborists and tree-service professionals should consider cleaning/sterilizing saws and pruning blades after cutting an infected tree and before using them on uninfected lauraceous tree species. The potential for transmission of laurel wilt by pruning tools is currently being investigated by researchers at the University of Florida. Tree-service and utility pruning crews should be careful not to transport RAB-infested host material over long distances on chipping equipment or in chip vans.

<u>Chemical Control</u>

At one site in Florida, macro-infusion of redbay trees with the fungicide propiconazole was demonstrated to protect healthy redbay trees from development of laurel wilt after artificial inoculation with the pathogen (Mayfield et al. 2008a). Continued monitoring of trees in that study into 2009 suggests that the treatment, properly applied, can protect redbay trees for at least a year, but probably not for 2 or more years (A.E. Mayfield III, unpublished data). The macro-infusion process, which has also been used to protect against vascular wilt diseases in other species (e.g., oaks and elms), is relatively labor intensive and expensive, so it is impractical to implement on a large scale. It is currently unknown whether repeated use of this treatment can successfully protect a redbay tree through the duration of a laurel wilt epidemic, and if so, how many times a tree can or should be treated before the treatments can be discontinued (if at all). Recent data suggest RAB populations remain relatively high for 7-8 years following initial discovery until they fall to very low levels after the redbay population is gone (J.L. Hanula, unpublished). Treatment of symptomatic trees has not been evaluated and is not recommended. Nonetheless, propiconazole macro-infusion may be an option for protecting individual, high-value, landscape redbay trees, at least in the short-term. Removal of diseased redbay or other host material from the immediate area around the treated tree may help reduce the possibility of RAB attacks. Research may eventually demonstrate the efficacy of other fungicides, insecticides, or methods of delivery against RAB and the laurel wilt pathogen. Because RAB populations thus far have continued at very low levels even when all apparent host material is dead, individually treated trees may need to be protected in perpetuity.

<u>Trap-Out or Attract and Kill</u>

Manuka oil is as attractive to RAB as freshly cut redbay wood (Hanula and Sullivan 2008), and healthy, unwounded redbay trees are somewhat less attractive than wounded trees (Hanula et al. 2008). Although not yet demonstrated, protecting healthy trees by drawing RAB away from them may be possible. Combining manuka oil with other potential attractants in traps, or combining it with an insecticide and applying the combination to non-host substrates, may be effective ways to help minimize RAB populations within limited areas such as parks, neighborhoods or barrier islands. These techniques might be used to eradicate low-level RAB populations from isolated areas such as barrier islands after laurel wilt has eliminated most mature redbay trees. Mass trapping could be tested in combination with sanitation and chemical control to protect redbay trees that survive the initial wave of mortality.

Germplasm Conservation

Seed collection is routinely used as a means to preserve the genetic diversity of a plant species. Although seed of many species can be dried, stored below 0^{o} C and remain viable for many years, long-term seed storage does not seem feasible for redbay. Due to their high lipid content, seeds of species in the Lauraceae are generally temperature recalcitrant, meaning it is difficult or impossible to sufficiently reduce the moisture content of the seed for storage at sub-freezing temperatures without killing the seed.

A protocol for collecting and submitting redbay seed to the USDA Forest Service National Seed Lab (NSL) in Dry Branch, GA was initiated in the summer of 2007 to determine the length of time redbay seed could be stored and to serve as a short-term storage facility for seed collected from impacted or potentially impacted areas.
(see http://www.fs.fed.us/r8/foresthealth/laurelwilt/seed_collection/seed_collection.shtml). Redbay seed from a wide variety of locations has been collected since 2007 and is being stored at the NSL. Using traditional methods, redbay seed can be stored for only a few years at 3^{o} C with significant losses in viability each year.

Because long-term seed storage using traditional methods is not an option, other alternatives have been discussed. Cryopreservation of embryos from seeds has been identified as a possible option, but is expensive and labor intensive to implement on a large scale. *Ex situ* conservation of trees outside the southeastern Atlantic Coastal Plain region is another possibility, but that would require funding and a coordinated effort among organizations from across the region. More survey and impact data on species like sassafras, pondspice and pondberry would also be needed to help support and justify *ex situ* conservation programs for laurel wilt hosts. Because long-term germplasm preservation of these species is unlikely without an extensive outlay of money and resources, it would seem necessary to first demonstrate some likelihood of re-establishment success of host plant species into laurel wilt-impacted areas. The persistence of low-level RAB populations on places like Hilton Head Island (where the laurel wilt epidemic has already run its course) currently calls this likelihood into question.

Discovery and utilization of resistant genotypes

Jason Smith (University of Florida) and colleagues are investigating the possibility of natural resistance to laurel wilt in redbay populations. Research has included identifying and taking cuttings from putatively resistant redbays (mature trees that have remained alive in areas heavily impacted by laurel wilt), rooting them, and growing them to a size where they can be evaluated for disease susceptibility. Though laurel-wilt resistant redbays are not yet known, research may lead to their availability and use in the future.

Integrated Pest Management Strategy

An integrated management strategy is needed to limit the spread and impact of laurel wilt. This strategy may take various forms depending on the area of interest. In many forests and other natural areas with a redbay component, the most reasonable management response where laurel wilt is established may be to simply let the disease run its course. "Recovery" from laurel wilt in redbay and other forest species could be considered in terms of the following general courses of action:

- Slow the long distance, human-assisted spread of the disease.
- Improve our understanding of the biology, host associations, and impacts of the disease and its vector.
- Protect individual, high-value landscape trees with pesticides when feasible.
- Develop other tools for management of the disease and its vector, possibly to include sanitation, other silvicultural methods, trap-out or attract-and-kill techniques, use of resistant genotypes, and biological control.
- Assess the need for, and possibly pursue, a germplasm conservation program for threatened hosts.
- Continue to monitor the geographic spread of the disease, assess its impacts on host species as its spreads to new ecosystems, and educate the public about the issue.

IX. Infrastructure and Experts

Those with expertise and experience with the laurel wilt issue on redbay and other forest species include, but are not limited to:

Research:

Vector:

- James Hanula, USDA Forest Service, Southern Research Station, Athens GA, 706-559-4253, jhanula@fs.fed.us
- Robert Rabaglia, USDA Forest Service, Forest Health Protection, Arlington VA; 703-605-5338; brabaglia@fs.fed.us
- Brian Sullivan, USDA Forest Service, Southern Research Station, Pineville, LA 318-473-7206, briansullivan@fs.fed.us
- Jorge Peña, University of Florida, Tropical Research and Education Center, Homestead, FL, 305-246-7001 ext. 223, jepena@ufl.edu

Pathogen:

- Stephen Fraedrich, USDA Forest Service, Southern Research Station, Athens GA, Athens, GA, 706-559-4273, sfraedrich@fs.fed.us
- Thomas Harrington, Iowa State University, Ames, IA, 515-294-0582, tcharrin@iastate.edu
- Jason Smith, University of Florida, School of Forest Resources and Conservation, Gainesville, FL, 352-846-0843, jasons@ufl.edu

- Randy Ploetz, University of Florida, Tropical Research and Education Center, Homestead FL, 305-246-7001 321, kelly12@ufl.edu

Other:

- Albert “Bud” Mayfield, USDA Forest Service, Southern Research Station, Asheville, NC, 828-667-5261 ext. 122, amayfield02@fs.fed.us
- Lissa Leege, Georgia Southern University, Statesboro, GA, 912-478-0800, leege@georgiasouthern.edu
- Joel Gramling, The Citadel, Charleston, SC, 843-953-6459, joel.gramling@citadel.edu
- Kent L Smith, USDA Agricultural Research Service, Washington, DC, 202-720-3186, kent.smith@ars.usda.gov
- The USDA/CSREES Current Research Information System website (http://cris.csrees.usda.gov/) contains descriptions of most of the current the public research on laurel wilt in the U.S.

Regional and State-Specific Information

Florida

- Ed Barnard, Florida DACS Division of Forestry, Gainesville, FL, 352-372-3505, ext. 130, barnare@doacs.state.fl.us
- Jeff Eickwort, Florida DACS Division of Forestry, Gainesville, FL, 352-372-3505, ext. 491, eickwoj@doacs.state.fl.us
- Trevor Smith, Florida DACS Division of Plant Industry, Cooperative Agricultural Pest Survey (CAPS), Gainesville, FL, 352-372-3505 ext. 452, smitht2@doacs.state.fl.us

Georgia

- James Johnson, Georgia Forestry Commission, Athens, GA, 706-542-9608, jjohnson@gfc.state.ga.us
- Chip Bates, Georgia Forestry Commission, Statesboro, GA, 912-681-0490 cbates@gfc.state.ga.us
- Scott Cameron, Georgia Forestry Commission, Richmond Hill, GA, 912-663-2566, scameron@gfc.state.ga.us

South Carolina

- Laurie Reid, South Carolina Forestry Commission, Columbia, SC, 803-896-6140, lreid@forestry.state.sc.us
- Andy Boone, DendroDiagnostics, Inc., Chapin, SC, 803-730-2930, dendrodiagnostics@gmail.com

Mississippi

- Randy Chapin, Mississippi Forestry Commission, (601) 833-6621, rchapin@mfc.state.ms.us
- John Riggins, Mississippi State University, (662) 325-2984, jriggins@entomology.msstate.edu

Southeastern U.S. and regional laurel wilt website

- Don Duerr, USDA Forest Service, Forest Health Protection, Atlanta, GA, 404 347-3541, dduerr@fs.fed.us

Regulatory

- Wayne Dixon, Florida DACS Division of Plant Industry, Gainesville, FL, 352-372-3505, ext 118, dixonw@doacs.state.fl.us
- Paul Hornby, USDA-APHIS-PPQ, Florida State Plant Health Director, Gainesville, FL, 352-313-3040, paul.l.hornby@aphis.usda.gov

Extension and Education

- Jonathan Crane, University of Florida, Tropical Research and Education Center, Homestead FL, 305-246-7001 ext. 290, jhcr@ufl.edu
- Carrie Harmon, University of Florida, Southern Plant Diagnostic Network, Gainesville, FL, 352-392-3631 ext. 254, clharmon@ufl.edu

Germplasm Conservation

- Victor Vankus, USDA Forest Service, Botanist, National Seed Laboratory, Dry Branch, GA, 478-751-3551

X. Research, Extension, and Education Priorities

<u>Research Priorities</u>

Short Term

- Determine utilization patterns of redbay, sassafras and other species at risk to laurel wilt by forest products industries, other businesses, and the public, and determine pathways by which RAB and laurel wilt could become established at other locations in the U.S. and the Americas. In particular, determine whether the distribution of "cypress blend" mulch, which may include redbay wood, is a pathway by which the RAB can spread to new areas.
- Determine the extent of infestation and rate of spread of the RAB and laurel wilt disease in sassafras populations.
- Determine the prevalence of RAB in Asian countries and evaluate potential pathways by which RAB and *R. lauricola* could be introduced from Asia into areas of the Americas currently free of these pests.
- Assess the need for, and perhaps seek funding and support for an *ex situ* germplasm conservation program for rare or endangered lauraceous plant species such as pondspice and pondberry, and possibly for redbay or other hosts threatened with drastic population reductions.
- Determine fate of RAB, *R. lauricola* and other *Raffaelea* species associated with RAB in ecosystems after redbays and other suitable hosts have died off.
- Evaluate the feasibility of protecting high-value landscape redbay trees with propiconazole on a repeated basis over an extended period of time. Evaluate the efficacy of other fungicides, insecticides, delivery methods, or combinations thereof.
- Continue research to better understand the epidemiology of laurel wilt on various plant species including better information on the biology and host attraction of the RAB and biology of *R. lauricola*.
- Determine the effect of other *Raffaelea* species associated with RAB on plants native to the U.S.
- Determine whether the use of contaminated pruning tools is a means by which the redbay pathogen can be spread from one tree to another.
- Determine and implement the best management strategies for slowing the movement of RAB westward along the Gulf Coast and northward along the Atlantic Coast in redbay, and inland in sassafras.
- Evaluate other lauraceous species in the U.S. and the Americas for attractiveness to the RAB, suitability for reproduction of the RAB, and susceptibility to the laurel wilt pathogen.

Long Term

- Develop and evaluate effective management strategies (alone and in combination) for the laurel wilt vector such as sanitation, other silvicultural techniques (e.g., use of prescribed fire), trap-out or attract and kill techniques.
- Research the biology and host interactions of RAB and laurel wilt in Asia to understand what limits populations of RAB in its native range.

- Search for and investigate the possibility of using biological control agents against the laurel wilt pathogen and/or vector. Determine if any of the *Raffaelea* species (other than *R. lauricola*) associated with RAB could be used as a biocontrol agent.
- Continue to research the possibility of natural resistance in redbay populations and the eventual use of resistant genotypes in the field.
- Determine the mechanisms of resistance in Asian host species.
- Determine if other ambrosia beetles established in the U.S. are capable of carrying and transmitting *R. lauricola* (or other *Raffaelea* species associated with RAB) to susceptible host plants.
- Determine the ecological impacts of laurel wilt in natural ecosystems, including impacts on host plant populations (notably pondberry and pondspice), plant community composition, herbivores of host plants and other associated fauna, and multi-trophic relationships.
- Determine the population levels of RAB and the threat of laurel wilt to redbay and other lauraceous hosts in the aftermath of epidemics.
- Continue work on the molecular biology of ambrosia beetle symbionts and related molecular identification techniques.

<u>Extension and Education Priorities</u>

- Encourage all agencies and individuals who produce research or extension publications, produce survey reports, or confirm new infested counties to contribute this information to the regional laurel wilt website hosted by the USDA Forest Service-Forest Health Protection, which currently serves as a clearinghouse for this type of information.
- Educate campers, hunters and other forest and park users about the risks associated with transporting firewood. Encourage park, campground and land managers in areas affected by laurel wilt to post signs or other materials that discourage the transportation of firewood out of RAB-infested areas.
- Educate state agency resource professionals such as foresters, extension agents, regulatory personnel and others that might recognize the disease and help promote a consistent message.
- Train nurserymen and nursery inspectors to recognize laurel wilt symptoms and ambrosia beetle attacks and to send suspect plant material or insect samples to proper authorities for identification.
- Conduct education/outreach programs that raise awareness of the laurel wilt issue to the following groups:
    - Those who cut, utilize, transport or dispose of host tree material (e.g., tree service companies, utility companies, loggers, mulch plants and pulpwood mills that utilize host species, landfills and transfer stations)
    - Growers and sellers of live host trees (e.g., container and field nurseries, avocado growers)
    - Owners of host trees in residential and landscape settings (e.g., homeowners, park managers, botanical gardens and arboretums)
    - Owners and managers of host trees in forested and natural settings (e.g., forest landowners, forest and natural areas managers, park managers)
    - Those who may transport firewood (e.g., hunters and campground visitors)
    - Other public agencies, administrators and politicians

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XII. Web Resources

- Regional Laurel Wilt Website hosted by the USDA Forest Service, Forest Health Protection, Southern Region. Includes disease information, updated distribution maps, publications, photos, and contacts: http://www.fs.fed.us/r8/foresthealth/laurelwilt/index.shtml

- Florida DACS Division of Plant Industry Laurel Wilt Page: http://www.doacs.state.fl.us/pi/enpp/pathology/laurel_wilt_disease.html

- Florida DACS Division of Forestry Laurel Wilt Page: http://www.fl-dof.com/forest_management/fh_insects_redbay_ambrosiabeetle.html

- Georgia Forestry Commission Laurel Wilt Page: http://www.gfc.state.ga.us/forestmanagement/LaurelWilt.cfm

- Mississippi Forestry Commission Laurel Wilt Page: http://www.mfc.state.ms.us/fh_laurel_wilt.htm

- A Standard Operating Procedure for Plant Diagnostic Laboratories: Laurel Wilt and the Redbay Ambrosia Beetle, is available through the National Plant Diagnostic Network http://www.npdn.org or by contacting Carrie Harmon at clharmon@ufl.edu.