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FOREST HEALTH

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Biology, Ecology, and Management of Laurel Wilt and the Redbay Ambrosia Beetle

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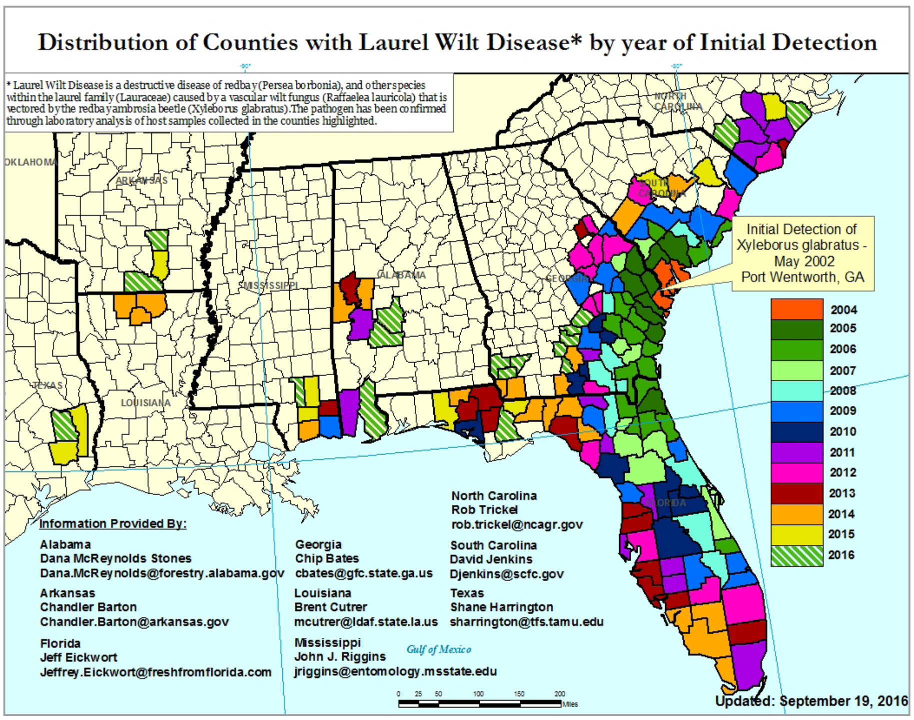

Figure 1. Distribution of laurel wilt infected counties (as of September 2016). Colors indicate year of initial detection. For an updated map, see http://www.fs.usda.gov/main/r8/forest-grasslandhealth.

Laurel wilt is a lethal tree disease caused by a fungal pathogen (*Raffaelea lauricola*), which is a nutritional symbiont of a non-native wood-boring beetle (the redbay ambrosia beetle, *Xyleborus glabratus*)[8,14]. The laurel wilt pathogen is carried and spread by the redbay ambrosia beetle, and host infections occur when the beetle attacks susceptible host trees. Shortly after the redbay ambrosia beetle was first detected in the U.S. in 2002, local redbay (*Persea borbonia*) trees began dying in unusually large numbers, and this mortality was eventually attributed to laurel wilt[8,10]. Since then, laurel wilt has spread across the Southeastern Coastal Plain in the eastern U.S., causing the death of millions of redbays in forested and residential areas. Additionally, sassafras (*Sassafras albidum*), avocado (*Persea americana*), and other native plants in the laurel family are susceptible and have experienced dieback and mortality. Due to its widespread distribution and the high level of mortality that laurel wilt causes in forests and natural areas, understanding and effectively managing this disease is necessary to maintain the health of southeastern U.S. forests and the plants, animals, and humans that rely on them.

Current Distribution

The redbay ambrosia beetle was first detected in 2002 near Port Wentworth, Georgia[10]. Laurel wilt has now spread to nine states in the southeastern U.S. (Fig. 1) and is likely to keep expanding to new areas. Laurel wilt is spread over long distances by the flight of the redbay ambrosia beetle and human movement of beetle-infested wood. Early in the invasion, it was estimated that the redbay ambrosia beetle was spreading at a rate of 34 miles/year[18]. Long range jumps in geographic distribution are suspected to be due to human movement of beetle-infested wood, a common transport avenue for wood-boring insects.

Plant Hosts

Laurel wilt affects members of the laurel family (Lauraceae) (Table 1). So far, redbay has been the species most impacted by this disease. Redbay is a broad-leaved evergreen tree known for its dark-green, leathery, and aromatic leaves (Fig. 2). Swamp bay (*Persea palustris*) and silk bay (*Persea humilis*) are closely related to redbay and are similar in appearance; however; there are minor differences in appearance and habitat. Sassafras

Table 1. Plant species susceptible to laurel wilt. Plants listed in **bold** were found to be susceptible in artificial inoculation trials, but have not yet been reported as naturally infected.

Common name	Scientific name
Redbay	*Persea borbonia*
Swamp bay	*Persea palustris*
Silk bay	*Persea humilis*
Sassafras	*Sassafras albidum*
Northern spicebush	*Lindera benzoin*
Pondberry	*Lindera melissifolia*
Pondspice	*Litsea aestivalis*
Camphortree*	*Cinnamomum camphora*
Avocado	*Persea americana*
Bay laurel	*Laurus nobilis*
California laurel	***Umbellularia californica***
Viñátigo	***Persea indica***
Gulf licaria	***Licaria triandra***

**The laurel wilt disease in camphortree is unlike that in other Lauraceae native to North America. While the fungus can move throughout camphortree tissues, presently, only a small percentage of infected camphortrees develop dieback – as such, this tree species appears to be more resistant than other Lauraceae in North America.*

is an aromatic deciduous tree or shrub that has a colony-forming growth habit, variable leaf shape, and interconnected root systems (Fig. 3). The movement of laurel wilt through the range of sassafras is a major concern as it may bring the disease to new geographic regions and forest types[24]. Camphortree (*Cinnamomum camphora*) is a large, exotic, evergreen tree with aromatic leaves. Laurel wilt in camphortree is generally not lethal; however, wilt and dieback can occur in infected branches[9]. Avocado trees in residential areas and commercial groves have succumbed to laurel wilt, raising more concerns as the disease moves closer to Mexico, the world's leading producer of avocado fruits[25]. The European bay laurel (*Laurus nobilis*), whose herbaceous leaves are used for cooking (bay leaves), is also susceptible to laurel wilt and the redbay ambrosia beetle[15].

Several additional tree species are susceptible to laurel wilt[16] (Table 1), and researchers are working to determine if other members of the laurel family are also affected.

The ability of the laurel wilt fungus to cause disease in North and Central American plant species is a new development, as laurel wilt or unusual levels of tree mortality have not been reported in association with the redbay ambrosia beetle or the laurel wilt fungus in their native region of Southeast Asia. It is possible that in the redbay ambrosia beetle's native range trees have developed a natural resistance to the fungus (meaning they are not susceptible to laurel wilt), while tree species in the United States have not developed any resistance. It is also possible that healthy host trees in the redbay ambrosia beetle's native range are not attractive to the beetle.

Beetle Identification

The redbay ambrosia beetle spends the majority of its life within the wood of infested trees, leaving the tree only to fly to and locate new hosts. The female redbay ambrosia beetle is small (2.0 – 2.5 mm long) and cylindrical in appearance (Fig. 4). The color of adult beetles is dark brown to nearly black, and they have a nearly smooth upper surface with few hairs, and pronounced downward

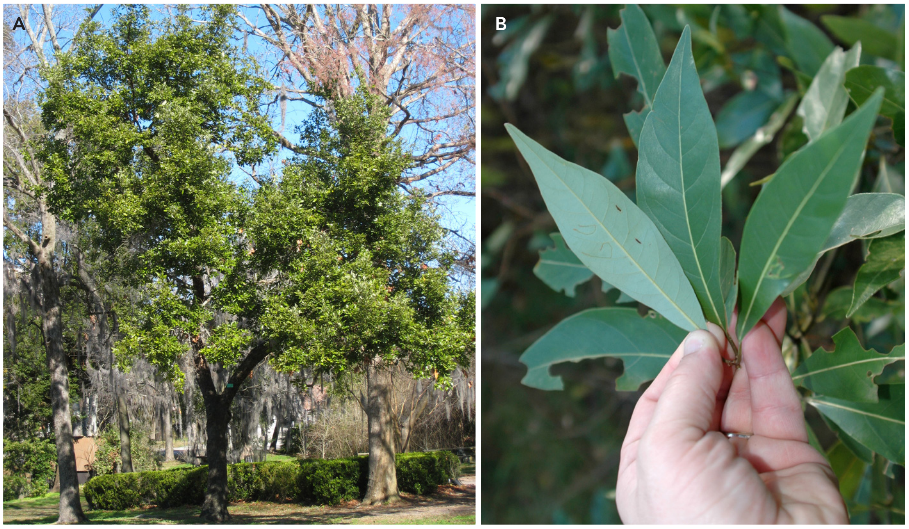

Figure 2. Mature redbay tree (Persea borbonia) *(A) and close-up of leaves (B).*

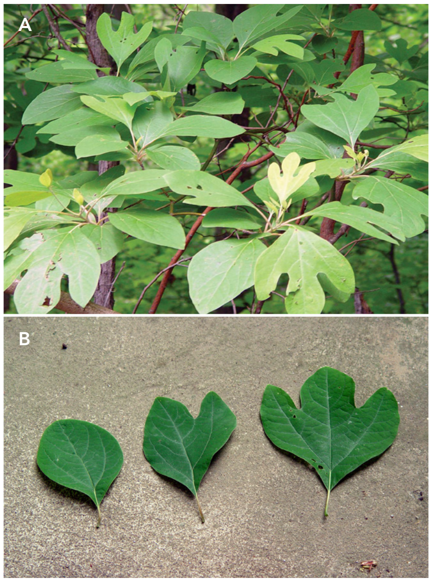

Figure 3. Sassafras (Sassafras albidum) *foliage (A) and variable leaf shape showing single-, double- and triple-lobed leaves (B).*

slope at the rear end (declivity). Male beetles are rare, slightly smaller, and have horn-like spines extending over the head[26]. Only females fly and have pocket-like structures called mycangia that hold fungal spores – as such, only females spread the laurel wilt fungus from tree to tree. Males remain in or near the host tree and aid in reproduction. Although nine other ambrosia beetle species have been found to carry the laurel wilt fungus after living in trees that have died from laurel wilt[5], there is no evidence yet that they are spreading the disease.

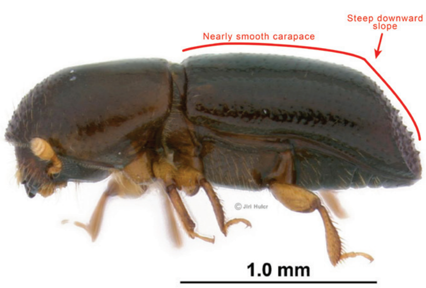

Figure 4. The exotic beetle responsible for spreading laurel wilt, the redbay ambrosia beetle (Xyleborus glabratus).

Symptoms

The most noticeable symptom of laurel wilt in highly susceptible species such as redbay, swampbay and sassafras, is wilting leaves and leaf color changing from green to brown across the entire canopy of the tree (Fig. 5a). At first, the wilt and leaf browning may develop from individual branches or sections of the tree. But, as the disease progresses, wilt will usually spread throughout the entire tree. In the case of redbay, swamp bay, and silk bay, wilted leaves may persist on the dead tree for up to a year or more, leaving a dead, standing tree full of brown leaves (Fig. 5b). Basal sprouts and epicormic branches on the stem will often emerge after the main stem dies; while this new growth may last for a number of years, it may also die rather quickly from systemic infection or new attacks by beetles. Attack by other species of ambrosia beetles is also common in trees infected with laurel wilt. Eventually, other beetles and fungi that invade the tree can cause stem weakening and breakage. In sassafras, symptom progression is slightly different. Because sassafras is deciduous, after the initial leaf wilt, the tree usually loses all its leaves[3] (Fig. 6). Another common symptom of laurel wilt is wood stain and/or discoloration (Fig. 7). Notable symptoms of ambrosia beetle attack include an accumulation of boring dust on the lower trunk or ground, small tubes of compacted wood dust coming out from the tree stem, and circular boring holes in the wood (Fig. 7).

Disease Cycle

Typically, ambrosia beetles attack and colonize stressed and dying trees, and healthy trees are rarely attacked. However, the redbay ambrosia beetle is distinct in that it will readily attack both healthy and stressed hosts (Fig. 8). The beetle is attracted to airborne odors emitted from the tree's trunk and leaves[17,20]. Once a host tree is located, the beetle will bore into the tree and fungal spores are released from the beetle's mycangia, beginning the infection process. The laurel wilt fungus colonizes the xylem tissue, causing the tree to respond in a way that disrupts water movement within the tree. The role of the laurel wilt fungus in this beetle-fungus system is to colonize the tunnel systems (galleries) created by the redbay ambrosia beetle, and penetrate and digest wood tissue; the fungus then becomes a food source for the adult and larval beetles. During the tree's decline, trees are often further attacked by additional redbay and other ambrosia beetles, which will construct and lay eggs in their galleries. Also, it is important to

Figure 5. Laurel wilt symptoms on redbay (Persea borbonia). *The most common symptom is wilt and discoloration of foliage (A), and brown leaves remain on the tree after the tree dies (B).*

Figure 6. Laurel wilt symptoms on sassafras (Sassafras albidum). Leaf wilt and discoloration (A and B) is followed by mid-season defoliation, dieback, and death (C and D).

note that after a tree dies from laurel wilt, other fungi will invade the tree and may produce fungal conks and structures; these are not the laurel wilt fungus. Once the young beetles complete their development, they leave the tree as the next generation of female beetles to find new hosts. This completes the disease cycle and takes about one to two months[2, 11]. In hosts with interconnected root systems (like sassafras and avocado), it is suspected that the laurel wilt fungus can move from tree to tree through the root systems[3,23]. Fungal movement through underground root connections allows the fungus to spread from a single diseased tree to adjacent trees without the need for an insect.

Impacts

Redbay is a common tree in coastal forests of the southeastern U.S. Since the arrival of laurel wilt, it is estimated that millions of redbay trees have died (F. Koch, unpublished data). In forests, the death of many large and mature redbay trees has resulted

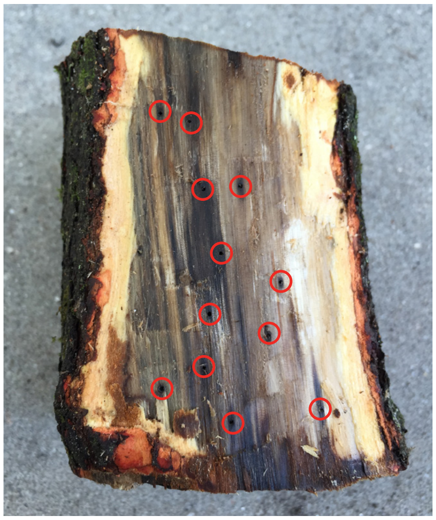

Figure 7. Black/brown wood discoloration in laurel wilt affected redbay (Persea borbonia). Redbay ambrosia beetle (Xyleborus glabratus) boring-holes are encircled in red.

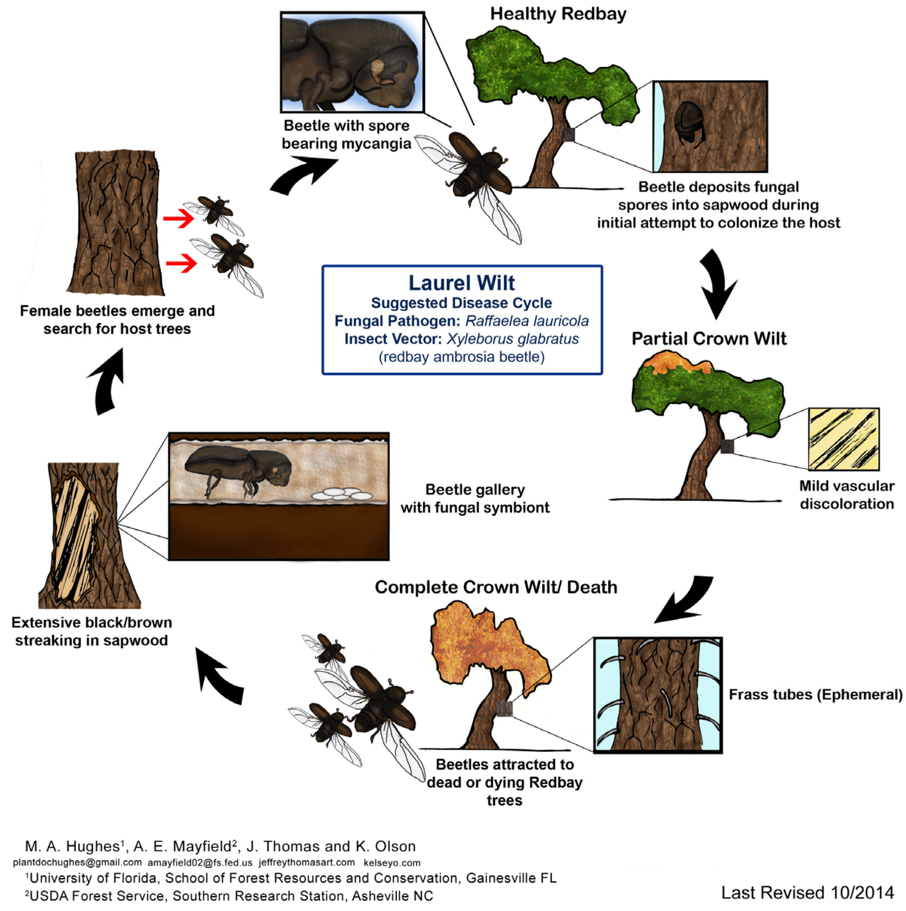

Figure 8. The laurel wilt disease cycle starts with a female redbay ambrosia beetle attacking a healthy host tree. The laurel wilt fungus is introduced into the tree, and as it grows the tree begins to show signs of disease. Tree death eventually occurs, and a new cohort of beetles emerges to find new host trees.

in an altered forest structure and composition. The redbay ambrosia beetle prefers to attack large trees[8, 21]; however, all size classes of trees are susceptible to the pathogen. Several animals utilize redbay as a food source including the spicebush and Palamedes swallowtail butterflies (Fig. 9a-c), redbay psyllid, and various other small mammals[6]. Additionally, several of these insects are pollinators, potentially indirectly affecting native plant populations[7] (Fig. 9d). The effects of laurel wilt on sassafras populations is still relatively small; however, as this disease expands into areas where sassafras is more abundant, levels of sassafras mortality may increase.

Figure 9. The impacts of laurel wilt can have many ecological implications. The spicebush (A, C) and Palamedes swallowtail (B) butterflies, (Papilio troilus *and* P. palamedes*, respectively) utilize redbay as a food source when in their (C) larval form (caterpillar). The yellow fringed orchid* (Platanthera ciliaris) *(D) is frequently pollinated by the Palamedes swallowtail and therefore could be indirectly affected by laurel wilt.*

Although redbay is a native forest tree with little commercial economic value, this species has value as an ornamental tree and is sometimes used for building boats and cabinets. It also has use as a medicinal plant in Native American culture (**http://www.naturalmedicinalherbs.net/herbs/p/persea-borbonia=red-bay.php**). Cities, municipalities, campgrounds, and homeowners may need to remove dead, standing trees when they pose a safety hazard to buildings, pedestrians, and vehicles, and the removal of these dead trees can be costly. Residential home values may also be affected when landscape trees are impacted (Fig. 10).

Management

MINIMIZE STRESS AND WOUNDS

Trees in poor health may be more likely to be attacked by the redbay ambrosia beetle; however, healthy trees can still be attacked, regardless of preventative arboricultural management. Nonetheless, trees that are stressed, either by flooding, root damage, open wounds, or other factors, release air-borne chemicals that may increase attractiveness to redbay ambrosia beetles and encourage beetle attacks. If pruning is needed, avoid months of peak beetle flight activity (March – April and September – October)[1,12] and perhaps wait for periods of colder weather, as redbay ambrosia beetle populations are generally lower during these times.

SANITATION

An infected tree left dead and standing provides resources for many generations of redbay ambrosia beetles to mature. Removal and destruction of all infested trees in an area may reduce populations of redbay ambrosia beetles, and thus may have potential to slow the spread of laurel wilt. However, redbay ambrosia beetles can also develop in stumps, so these would need to be ground down to below soil level. Cutting down infected trees, chipping the stem and branches (Fig. 11), and then covering the pile of wood chips with plastic (preferably leaving the pile in full sunlight) can be effective to reduce redbay ambrosia beetle populations[27]. This method works because chipping physically destroys the beetles' habitat and hastens wood drying, both of which are important factors in sanitization. Covering the wood chip pile may help to increase the temperature and "cook" the insects and fungi still in the wood. If chipping is not

Figure 10. Large residential redbay tree killed by laurel wilt. Removal of the tree will be necessary as it harbors the redbay ambrosia beetle and will soon decay, becoming a safety hazard.

feasible, then cutting down the stem and leaving the pieces on-site is recommended. Covering wood in plastic and/or burial may be helpful as it limits insect access into and out of infested logs. Infested wood should be left, burned, or buried on-site. Please **do NOT** move infested wood to areas that are free of laurel wilt – see **http://dontmovefirewood.org/** for the rules and recommendations of wood movement.

Figure 11. Infested redbay wood after being chipped. The small chips dry out quickly, and are not suitable habitat for redbay ambrosia beetle development.

Unfortunately, sanitation is unlikely to completely eliminate redbay ambrosia beetles from an area because their populations can linger at low levels for long after the most obvious host material is gone[13,19].

CHEMICAL CONTROL

Unfortunately, insecticides have limited effectiveness for the long-term protection of susceptible trees from insect attack. Root-flare injection with the fungicide propiconazole (trade names: Alamo® and Tilt®) can temporarily protect healthy trees from disease if applied prior to redbay ambrosia beetle attack and infection[22]. **Application of restricted use pesticides must be performed by a trained professional following label directions – IT'S THE LAW!** Currently, there are no sprays or drench-applied products available to homeowners that are effective against laurel wilt.

ENCOURAGE REGROWTH

After wilt and death, redbay trees in an area will often regrow from seeds or root and stump sprouts - often in very high numbers[4]. This, coupled with the decline in redbay ambrosia beetle populations following the death of suitable host material (larger trees), should allow trees to reach seed bearing age[19]. Researchers are monitoring the growth trends of this regeneration to see if this occurs[4]. In the short term, this re-growth can serve an ecological role by sustaining the species within forests and serving as host material for a variety of insects and animals.

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Resources

For the location and phone numbers of state agencies in the southeastern U.S. providing forestry assistance and information, see the following websites:

Alabama Forestry Commission: http://www.forestry.alabama.gov/

Arkansas Forestry Commission:
http://forestry.arkansas.gov/Pages/default.aspx

Florida Forest Service: http://www.floridaforestservice.com/

Georgia Forestry Commission: http://www.gatrees.org/

Kentucky Division of Forestry:
http://forestry.ky.gov/Pages/default.aspx

Louisiana Department of Agriculture and Forestry:
http://www.ldaf.state.la.us/

Mississippi Forestry Commission: http://www.mfc.ms.gov/

North Carolina Forest Service: http://www.ncforestservice.gov/

Oklahoma Forestry Services: http://www.forestry.ok.gov/

South Carolina Forestry Commission:
http://www.state.sc.us/forest/

Tennessee Division of Forestry:
https://www.tn.gov/agriculture/section/forests

Texas A&M Forest Service: http://texasforestservice.tamu.edu/

Virginia Department of Forestry: http://www.dof.virginia.gov/

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Alabama Cooperative Extension System:
http://www.aces.edu/main/

University of Arkansas Cooperative Extension Service:
http://www.uaex.edu/

University of Florida's Institute of Food and Agricultural Sciences (UF/IFAS):
http://solutionsforyourlife.ufl.edu/

University of Georgia Extension: http://extension.uga.edu/

Kentucky Cooperative Extension Service:
https://extension.ca.uky.edu/

Louisiana Cooperative Extension Service:
http://www.lsuagcenter.com/

Mississippi State University Extension Service:
http://extension.msstate.edu/

North Carolina Cooperative Extension:
https://www.ces.ncsu.edu/

Oklahoma Cooperative Extension Service:
http://www.oces.okstate.edu/

Clemson Cooperative Extension (South Carolina):
http://www.clemson.edu/extension/

University of Tennessee Extension:
https://extension.tennessee.edu/

Texas A&M AgriLife Extension: http://agrilifeextension.tamu.edu/

Virginia Cooperative Extension: http://www.ext.vt.edu/

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Association of Consulting Foresters:
http://www.acf-foresters.org/acfweb.

Click on "Find a Forester", then select your state in the "People Search – Public" search page.

For more information on how to select a consulting forester, go to:

http://msucares.com/pubs/publications/p2718.pdf

http://texashelp.tamu.edu/011-disaster-by-stage/pdfs/recovery/ER-038-Selecting-a-Consulting-Forester.pdf

http://www.uaex.edu/environment-nature/forestry/FSA-5019.pdf

Additional information on laurel wilt and the redbay ambrosia beetle is available at:

http://southernforesthealth.net/

http://laurelwiltresearch.com

http://www.dontmovefirewood.org/

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