Georgia Forest Pest Management Manual

This manual was developed in cooperation with the University of Georgia D.B. Warnell School of Forestry and Natural Resources, University of Georgia Cooperative Extension Service, and Georgia Department of Agriculture.

This training manual is presented in a printed version. This material is intended to provide the information necessary for you to meet the standards of the Environmental Protection Agency for pesticide certification in the Forest Pest Control category and to prepare you to take Georgia's commercial applicator certification examination for Category 23, based on this manual. This manual is not designed to provide you with all of the information needed for forest pest control. See publications listed in the "Suggested Reading" section of this manual for additional information on pest control and forest management. For other materials and for information on short courses, contact the Warnell School of Forestry and Natural Resources, University Cooperative Extension Service, State Forestry Commissions/Departments, and the USDA Forest Service offices. This manual is designed to complement, not to take the place of, the information contained in the 2014 2nd Edition of the National Pesticide Applicator Certification Core Manual.

The manual is available on our web site at http://www.bugwood.org/pestcontrol/. It contains high-resolution color versions of the images included in the printed manual, as well as links to other online resources and additional images.

Images from the publication as well as additional images are from and available on the Forestry Images web site: http://www.forestryimages.org/. Forestry Images is a joint project between the University of Georgia - Bugwood Network and the USDA Forest Service. For additional information on pesticide safety and commercial applicator licensing requirements and steps, visit the UGA Extension Pesticide Safety Education Program's website at https://extension.uga.edu/programs-services/pesticide-safety-education.html

You can order a hard copy of this manual from the UGA Extension Publications Store (https://estore.uga.edu/C27063_ustores/web/classic/store_cat.jsp?STOREID=203&CATID=778&SINGLESTORE=true).

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FOREST PEST MANAGEMENT

CONTENTS

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FOREST RESOURCES

Georgia has more forested acres than any other state in the southern United States, excluding Texas. Approximately 24.26 million acres of Georgia's 37.06 million acres are classified as forest land, or 64% of state's land area. As of 2017, private landowners (including corporate ownership) owned the most forest land in the state (84%), followed by forest industry (5%), the U.S. Forest Service (4%), other federal agencies (4%), and state and local government (3%). Over the past twenty years, nonindustrial private forest ownership has increased substantially from 72% in 1997 to 84% in 2017, while forest industry ownership declined from 21% in 1997 to 5% in 2017. Other land ownerships remained relatively stable over this period.

Georgia's forest resources are a major contributor to the state's economy. As of 2019, forestry, agriculture, and mining had the 7th highest output of all major industries in the state. During 2019, the timber industry produced an estimated total revenue of almost $22 billion. That same year, the forestry sector employed over 55,000 people across the state and accounted for over $3.9 billion in wages and compensation. A tremendous amount of wood volume is harvested each year. In 2018, Georgia's forests accounted for 1,365,961 cubic feet of timber products processed at about 193 mills across the state as well as facilities in surrounding states. Pine and hardwood pulpwood accounted for 42.6% of the total followed by saw logs (35.0%), bioenergy and fuelwood (8.4%), composite panel (7.8%), veneer logs (2.8%), miscellaneous products

(1.7%), and poles and posts (1.7%). The U.S. South is the nation's leader in pulpwood and lumber production, and Georgia ranks as the number one state in terms of annual timber harvest. Forest industry has achieved its ranking while the state's total wood volume has been increasing slightly since 1953.

Major Species

The humid, temperate climate and varied physiographic provinces and their associatedgeologies and soils result in high woody plant diversity across the state. Georgia has about 250 native tree species, and 90 of those species are considered commercially important. Pines are the most important commercial species in terms of economic andvolume output in Georgia and the Southeast. The four major species used by the forestproducts industry are loblolly, slash, longleaf, and shortleaf pine. Pines are used for a variety of products including: pulp (fiber and biomass), lumber, poles, plywood, oriented-strand board, chemical extracts, mulching (e.g. pine straw), and other commodities. Cypress is another valuable conifer species in Georgia, with demand for saw logs and mulch, but it occupies a much smaller area than any of the pine species, as it is limited to bottomland areas near rivers, swamps, ponds, and coastal areas.

Oaks are the most commercially important hardwood species in the state. White oak species typically receive higher stumpage prices than common red oak species, such as northern red oak, southern red oak, and black oak. Depending on species, wood quality, and grade, oaks may be used for veneer, barrel staves, furniture, flooring, cabinets, construction timbers, crossties, posts, fuel, and pulp. Sweetgum, yellow-poplar, and hickory, where local markets exist, are used for pallets, crossties, furniture, lumber, pulp, and several other specialty items. Hybrid sweetgum, sycamore, and cottonwood may be locally important for energy biomass or pulp. Hardwood sawtimber stumpage prices are typically higher than pine stumpage prices for species such as oaks, but pulp prices for pine and hardwoods vary significantly by location in the state.

Major Forest Types

Six broad forest types comprise 98% of the forested acreage in Georgia. Each forest type or naturally occurring aggregation or grouping of tree species, is named for the predominant tree species that occur.

LOBLOLLY-SHORTLEAF PINE (Figure 1, pg 94) occupies 30% of the forested land area in the state, with loblolly pine being the most dominant species in this forest type. Loblolly pine accounts for 39% of all live trees in the state and represents 32% of standing timber volume. Other commonly occurring species in this forest type include: oaks, hickories, blackgum, sweetgum, and occasionally, red maple. This forest type is common throughout the Coastal Plain and Piedmont physiographic regions.

OAK-HICKORY FOREST (Figure 2, pg 94) is the second most broadly occurring forest type in the state in terms of land area occupied. This type occurs on 26% of the state's forest land area. Oaks or hickory, singly or in combination, comprise over 75% of stand stocking or stem densities. Other species commonly associated with this type include: yellow-poplar, elms, maples, blackgum, sweetgum, sourwood, and occasionally, black walnut. The oak-hickory type is prevalent in portions of the Piedmont, as well as the Blue Ridge, Ridge and Valley, and Cumberland Plateau physiographic regions in the northern half of the state.

LONGLEAF-SLASH PINE FOREST TYPE (Figure 3, pg 95) comprises 15% of the state's forested area. Slash pine is dominant in this forest type, and it comprises 84% of the total stocking in this group. Common species associated with this type may include: post oak, blackjack oak, water oak, laurel oak, sweetgum, blackgum, persimmon, hickories, dogwood, bald cypress, water tupelo, gallberry, titi, and palmetto, depending on site moisture gradients. The longleaf-slash pine type is located in the Coastal Plain physiographic province.

OAK-GUM-CYPRESS TYPE (Figure 4, pg 95) is the second most common hardwood forest type found throughout the state and comprises 14% of the state's forest area. Blackgum, tupelo, sweetgum, oaks, and cypress, singly or in combination, comprise greater than 75% of stand stocking. It is prevalent in bottomland areas of the Coastal Plain of Georgia. Other common species found in this type include: cottonwood, willows, ash, elms, sugarberry, and maples.

OAK-PINE TYPE: (Figure 5, pg 96) The mixed oak-pine type comprises 11% of the state's forest land. Upland oaks are the primary hardwood species, but pines (usually loblolly or shortleaf pine) constitute 25 to 50% of the stocking or stand stem density. Other common hardwood species in this forest type include: sweetgum, hickories, maples, and yellow-poplar.

ELM-ASH-COTTONWOOD TYPE FOREST (Figure 6, pg 96) is another bottomland hardwood forest type that comprises about 2% of Georgia's forest land area. This type is most prevalent in bottomlands of the Piedmont physiographic province. Elm, ash, or cottonwood, in combination or individually, occupy the majority of the stand stocking. Other common hardwood associates include: sycamore, willows, and maples.

TREE NURSERIES: As has been the trend for many years, more forested acres are planted in the southern United States than any other region of the country. In 2019, approximately 80% of tree planting and production occurred in the southern states. More than 2.5 million acres were planted in the United States in 2019. U.S. nurseries produced over 1.3 billion seedlings. Of these seedlings, about 75% are bareroot stock. Only three percent of the total seedlings produced in the U.S. were hardwood species. Georgia nurseries accounted for over 25% of the tree seedlings produced in the U.S. during 2019. Over 330 million tree seedlings were produced in Georgia, while only 1.4% of seedlings produced in the state were hardwoods. Across the state, over 600,000 acres were planted in 2019. In order to produce quality seedlings, forest nurseries utilize the most current methodology in all steps of seedling production. Cultural activities include: seedbed preparation and sowing, irrigation, fertilization, chemical weed management, pest management through use of fungicides and insecticides, and seedling handling, which includes lifting, packing, and storage, are all practiced using up-to-date scientific protocols. Methodology for these many different aspects of tree seedling nursery production are constantly being refined and updated.

PRINCIPLES OF FOREST MANAGEMENT

Interest in protecting forests from disease, insect, weed, and vertebrate pests is important in keeping a forest healthy. This interest has grown largely because of:

1. increased awareness and knowledge of the destructive capacities of pests;
2. the large impact forest pests have on commercial timber supplies and aesthetic values;
3. environmental concerns;
4. effects on threatened and endangered species; and
5. availability of new, specific pesticides.

Foresters and landowners have come to realize that much of the damage caused bypests can be avoided or minimized. Knowledge of pest identification and biology, combined with good forest management practices, can prevent or at least reduce losses due to pests. Forest stands and trees in a healthy, vigorous growing condition are much better able to withstand damage by pests than trees already under stress.

Using a combination of prevention and suppression methods is the best approach to managing forest pests. Integrated pest management (IPM) involves employing the best prevention and management strategies. IPM is discussed in the National Pesticide Applicator Core Manual. Pest management should be a part of an overall forest management plan. The need for pest suppression treatments can often be minimized through wise, long-term forestry practices. The appropriate pest suppression method(s) will depend upon the kind and amount of suppression necessary, balanced with costs and benefits within legal, environmental, and other constraints. The most important principle of pest suppression is to use a chemical suppression method only when necessary to prevent unacceptable levels of damage. Even though a pest is present, it may not be necessary to apply pesticides. The damage or losses may not merit the expense of chemical pest management tactics.

Before making management decisions, managers should evaluate potential pest impacts within the context of the ecosystem in which the organism occurs, as well as the population dynamics of the organism. Will the impact of an organism increase, decrease, or maintain its level of damage over time? What part(s) of the tree does the pest affect? How many trees are or may be affected? What will be the long-term impact of these organisms? Does the organism cause permanent or only temporary damage? For example, many foliage feeding insects, such as oakworms, cause a one-time defoliation from which the tree can recover. Most deciduous trees can withstand complete one-time defoliation without significant long-term impact on tree health. However, gypsy moth can cause multiple defoliations, which can have a much more detrimental impact on tree and forest health.

Before choosing a management method(s):

1. Correctly identify the organism to ensure it is a pest.
2. Monitor the pest populations and determine the likelihood of economic damage.
3. Review available suppression methods.

4. Know and follow local, state, and federal regulations that apply.
5. Evaluate the benefits and risks of each available treatment method or combination of methods.
6. Determine whether there are any threatened or endangered species in the area to be treated.
7. Choose the method(s) that are effective yet will cause the least harm to you, others, and the environment.
8. Correctly carry out the suppression practice(s) and keep accurate records.

If other management options do not yield satisfactory results, you may need to apply a pesticide to suppress an undesirable pest in the environment. The challenge is to use pesticides in a manner that will cause the least harm to non-target organisms in forests while achieving the desired management goal.

Pesticides are tested and labeled for specific pests, crops, and for land-use situations. Use of insecticides, fungicides, and herbicides is common in managed seed orchards, forest nurseries, intensive short-rotation plantations, and in Christmas tree production. In general, the most commonly used forest pesticides are herbicides used for site preparation, herbaceous weed suppression, and in pine release treatments. Insecticides are seldom used in general forest management, as the expense of treatments is often not warranted given the amount of insect damage, they may not be able to be cost-effectively applied for the suppression needed, or the insect damage patterns are hard to predict making insecticide use impractical. Nantucket pine tip moth (*Rhyacionia frustrana*) suppression in loblolly pine (*Pinus taeda*) plantations when in the establishment phase is the exception. Currently, the only disease suppression treatment common in general forestry field applications is for annosus root rot. Vertebrate animals are sometimes suppressed through trapping or hunting, but repellents and poison baits may be employed.

INSECTS

Insects can cause aesthetic damage or mortality of forest and shade trees in the South (Table 1, pg 10). All parts of a tree can be susceptible to insect attack, including roots, trunks, limbs, leaves, and even logs waiting to be sawed into lumber. There are many different kinds of native insects in forests, including predators, parasites, herbivores, and pollinators. Forests have many layers of habitat for insects–from the top of tree canopies all the way down into streams. Most insects living in forest environments are healthy parts of natural systems. Many insects that eat plants, including trees, are not problematic. However, sometimes an outbreak can occur, and trees are killed or damaged. While outbreaks are usually short-lived, these damaging incidents can vary in frequency, duration, size, and degree of economic damage. Trees are less susceptible to attack from most insect pests when they are healthy. Thus, the most important preventative measure for pest insect damage is to maintain healthy forest stands.

Insects that cause tree health issues can be native, non-native, or invasive. Native insects in the Southeast have been historically located in the region and have co-evolved with native trees. Non-native insects originate from outside of an area and did not co-evolve with native plant hosts. Many non-native insects will acclimate to a new area but will not become a significant problem.

However, sometimes a non-native insect can become invasive. An invasive species "is not native to an ecosystem and its introduction does or is likely to cause economic or environmental harm or harm to human health" (www.bugwood.org). Invasive species covered in this section include emerald ash borer, hemlock woolly adelgid, gypsy moth, and Asian longhorned beetle.

The insects covered in this section are organized into topics based on how they damage trees. Topics include bark beetles, boring insects, chewing insects, defoliating insects, and sucking insects. General information is given on a few insects within each topic. Specific management information for each species can be found in the Forest Insect Resources Table (Table 2, pg 34) and the current Georgia Pest Management Handbook, Commercial Edition. Please contact your local University of Georgia County Extension agent or the Georgia Forestry Commission for additional guidance.

Table 1. Impact of Selected Forest Insects in Georgia[1]

Pest	Native or Non-Native	First Detected in GA	Host	Affected Areas
Elm leaf beetle	Non-Native	introduced to US in 1830s	Elm	30 counties in Northeast GA
Emerald ash borer	Non-Native	2013	Green Ash	37 counties in north GA and Atlanta Metro Area
Hemlock woolly adelgid	Non-Native	2002	Eastern Hemlock, Carolina Hemlock	Entire natural range of hemlock in North Georgia
Ips engraver beetle	Native	n/a	Southern Pine Species	624 acres in 2019-2020[2]
Southern pine beetle	Native	n/a		318 acres[2]

[1]Data obtained from the Georgia Forestry Commission's 2019 and 2020 Forest Insect and Disease Reports. This information only reflects damage in 2019-2020. Forest insect damage varies from year to year, with some years experiencing much higher damage levels
[2]Surveys in 2020 were limited due to COVID-19 restrictions.

Bark Beetles

Bark beetles are a group of beetles that bore into trees and feed under the bark by creating tunnels called galleries in the inner bark. The vascular tissue of trees is like a “two-way street” made up of tissues called xylem and phloem. Xylem is the outer part of the wood, and it moves water up from the roots to the rest of the tree. Phloem is located just under the bark and moves glucose and starch made from photosynthesis in the leaves down to the rest of the tree. Bark beetle galleries cut through the phloem, stopping movement of materials within the tree. This process, which eventually kills the tree, is called girdling.

Because beetles are feeding under the bark, their damage can often go unnoticed until the tree is dead or nearly dead. The first sign of a bark beetle infestation is small holes in the trunk usually oozing sap and are referred to as “pitch tubes”. In trees that are already unhealthy, the pitch tubes may not be present. The crown of an infested pine will fade from green-to-yellow-to-orangish brown. Once the crown has turned this orangish color, the tree is already dead, but often this is when people first notice that a tree has a problem. Boring dust, which has the appearance of fine sawdust, can be present near the base of a tree. Boring dust is caused by insects that move in to feed on the tree after bark beetles have killed or nearly killed the tree. Some bark beetle species feed on hardwoods, such as elm and hickory, causing sporadic damage. However, bark beetle species that attack pine are more of an issue to forestry in Georgia.

The main bark beetle pests of southern pines are southern pine beetles (SPB), black turpentine beetles (BTB), and *Ips* (engraver) beetles. Trees can be infested with numerous species of bark beetles at one time. A tree can be overwhelmed when these beetles attack pine trees in large numbers, a phenomenon called “mass attacks”. The defenses of the tree are not sufficient to prevent infestation of so many beetles. Trees that are already unhealthy are especially susceptible to bark beetle infestations. Tree stress can be caused by overcrowding of trees, root compaction, mechanical damage, drought, storm damage, etc. The amount of bark beetle damage on the landscape can increase when a larger-level environmental stressor occurs, such as a drought, where many trees have compromised health.

In addition to the damage beetles cause under the bark, southern pine beetles and engraver beetles carry and introduce blue stain fungi into pine trees. While damage from a bark beetle attack is often sufficient to kill a tree, the fungi clogs the water- conducting tissues in the tree, hastening tree death. Many other insects will colonize a dying pine tree once the bark beetles begin killing it. Larger pine sawyer beetle larvae, termites, ambrosia beetles, and other decomposers may be present. Often determining the exact cause of tree death can be difficult due to the activity of multiple insect species.

Keeping pine stands healthy decreases the likelihood of bark beetle attacks. Thinning pines at appropriate times, vegetation control, and wise use of fire as a management tool are parts of managing bark beetle risk. Contact Georgia Forestry Commission, a registered forester, or UGA Extension agent for pine management guidance.

SOUTHERN PINE BEETLE – Southern pine beetle (SPB), *Dendroctonus frontalis*, a small bark beetle less than ¼ inch long, can attack healthy pine trees (Figure 7, pg 97). Female SPB create galleries in the tree to lay eggs (Figure 8, pg 97). Once it hatches, each larva digs its own gallery, feeding on and damaging the pine tree. SPB galleries have an S-shaped curvy appearance. A single SPB female can lay eggs in multiple trees. It can take as little as 26 days for a SPB to go from egg to adulthood in warmer weather. SPB can have up to nine generations a year in some areas of the south.

SPB are normally present in forests in low levels feeding on stressed trees. However, they can have outbreaks that cover hundreds or thousands of acres. A SPB "spot" describes an area were SPB are actively killing or have already killed numerous trees. The leading edge of the spot is the area where new tree colonization is occurring. The SPB spot grows by the leading edge expanding into uninfested trees. The spot can expand by up to fifty feet in one day.

Signs of a SPB infestation include fading crowns, yellow and green needles on the forest floor, and pitch tubes usually in the bark crevices. SPB infestations often start around 20 feet up the tree trunk, or bole, but may range from 4 feet high all the way up into the canopy. No actions can save a pine tree once SPB attacks. Insecticides are not recommended to stop a SPB infestation.

BLACK TURPENTINE BEETLE - The black turpentine beetle (BTB), *Dendroctonus terebrans*, at approximately 1/3 inch long, is the largest southeastern US bark beetle species (Figure 9, pg 97). It has 2.5 – 3 generations a year and generally attacks unhealthy or damaged trees. Female BTB infest the pine trunk lower on the bole, up to 12 feet off of the ground. The galleries they tunnel are 8 – 12 inches long, and the larvae feed in a cluster rather than branching out on their own long galleries like other bark beetles (Figure 10, pg 97).

Multiple BTB life stages – adults, larvae, and pupae – can be found under the bark clustered together. BTB does not always kill pine trees, since it feeds in clusters in a limited location on the bole and does not generally transmit blue stain fungi. The limited feeding area under the bark means that trees may not be completely girdled as with other bark beetles. However, if BTB attack the same tree for multiple years or for many generations, then tree mortality may occur.

Signs of a BTB infestation include fading crowns, large (1–1.5 in) pitch tubes lower on the tree, and reddish-brown boring dust. Preventative contact insecticide control measures may successfully reduce the likelihood of a BTB attack since the BTB feeding area is restricted to the lower trunk.

ENGRAVER BEETLES – Engraver beetles (also called *Ips* beetles) are a group of bark beetles from the genus *Ips*. There are four engraver beetle species in Georgia: Small southern pine engraver(*Ips avulsus*), eastern five-spined Ips (*Ips grandicollis*), pine engraver (*Ips pini*), and six-spined Ips (*Ips calligraphus*). *Ips pini* is only located in the Appalachian region of Georgia, while the other species are distributed throughout the state. Engraver beetles can be distinguished from other bark beetles by their excavated (scooped out appearing) posterior that is surrounded by spikes or projections (Figure 11, pg 98). They are less than ¼ inch long, dig branching galleries (Figure 12, pg 98), and have numerous generations each year. Engraver beetles transmit blue stain fungi, which hastens tree death.

Engraver beetles usually attack stressed, unhealthy trees, as well as mechanically damaged trees and branches and tree residues left after logging (logging slash). Usually, engraver beetles attack isolated unhealthy trees, but when conditions are unfavorable, then infestations can extend through entire stands. Drought, flooding, construction activities, lightning strikes, and wind damage are just some of the unfavorable conditions that can lead to more widespread engraver beetle attacks. As tree health decreases, trees are increasingly susceptible to engraver beetle attacks. More than one engraver beetle species can attack a tree at one time. While often people are more fearful of SPB attacks, engraver beetle infestations are more common.

Signs of engraver beetle infestations include a fading crown, flowing small pitch tubes (<1/4 inch) often located on the bark plates, and reddish-brown sticky boring dust. Because engraver beetles attack unhealthy trees, pitch tubes may not be apparent. Stressed trees may not have the resources to produce the pitch tubes, in which case only small dry holes are visible on the outside of the bark. Preventative insecticide control measures are only economical for high value trees. Systemic and contact insecticides will not stop engraver beetle actively infesting a tree.

AMBROSIA BEETLES - Ambrosia beetles are a group of beetles that are closely related to bark beetles. Different ambrosia beetle species infest different tree species. They create tunnels to have a location to grow fungi, which their larvae eat. Ambrosia beetle activity in pine trees is a natural part of tree decomposition. They do not kill the pine trees, rather, they infest the dead and dying tree material.

The sign of ambrosia beetle infestation is small boring dust tubes protruding from the trunk, which then fall to the ground as dry, lighter colored boring dust. The appearance of the fine sawdust-like boring dust is an indication that the tree is dead or nearly dead. Pines cannot be saved once ambrosia beetle signs are present.

PINE BARK BEETLE CONTROL

Silvicultural techniques

The most effective way to prevent bark beetle infestations is to maintain healthy pine stands. Reducing stress caused by overcrowding, equipment damage, and root compaction reduces the likelihood of bark beetle infestations. Removing dead trees and slash can reduce risk, but this is not economically feasible for individual trees that have been attacked by BTB or engraver beetles. Salvage logging is more operationally feasible when larger areas have been infested.

SPB infestations are different than other bark beetle infestations in that they can outbreak and begin attacking healthy trees. SPB spots require special silvicultural techniques to stop an outbreak. The actively infested trees at the leading edge of a SPB spot, as well as a buffer of uninfested trees in front of the leading edge, must be cut. The buffer may need to be as much as 2.5 times the length of the tree height. The size of the buffer strip depends on speed of the spot advancement and the time delay in getting a logging crew to the site. The leading edge must be marked just before cutting, as the spots can expand up to 50 feet a day. Salvage logging for uninfested trees may be possible. Sometimes if removal of logs is not possible, spots can be managed by culling trees in the buffer zone and leaving them in the forest. This practice is often referred to as 'cut and leave'. Please contact the Georgia Forestry Commission and a registered forester when you suspect that you have a SPB spot, for additional details and guidance.

Insecticides - Insecticides are not recommended for most bark beetle infestations. Once a tree is being attacked by bark beetles it is very unlikely that insecticides will be effective. Insecticides are never appropriate for SPB infestations. Systemic insecticides can be used as a preventative for engraver beetles and BTB infestations for higher value trees. Contact insecticides are most feasible as a preventative for bark beetle infestations, targeting beetles as they enter the tree. For BTB infestations, only the bottom 12 feet of the bole would need to be treated using a backpack sprayer. Contact insecticide treatments as a preventative for engraver beetles would require spraying the entire bole and larger branches with a high-pressure sprayer, which is much more difficult, costly, and not a reasonable option for most settings. In addition, these entire bole sprays pose a greater risk for non-target impacts. Contact insecticides might need to be applied more than once in a season, and unfortunately, there is no clear guidance on treatment time intervals in the Southeast.

Boring Insects

Boring insects infest tree shoots, twigs, trunks, and roots. They also may feed onand seek shelter in wood. Insects that feed on young branch shoots can be particularly problematic in the younger trees of a regenerating forest or stand,tree nurseries, and ornamental settings. Insects covered in this section that are problematic for younger stands include the Nantucket pine tip moth, white pine weevil, and deodar weevil.

Some insects bore into tree trunks, compromising wood quality. Insects covered in this section that bore into tree trunks are native wood borers, emerald ash borer, and Asian longhorned beetle. Most native wood borers are secondary invaders, attacking the bark and wood of trees that are seriously weakened, dying, dead, or recently cut. Insects that infest wood products are not covered in this manual but are discussed in other Pest Control Operator manuals.

NANTUCKET PINE TIP MOTH (*Rhyacionia frustrana*) (NPTM) and another closely related tip moth, the subtropical pine tip moth (*Rhyacionia subtropica*) feed on young pines in the Southeast. While the subtropical pine tip moth may be present, NPTM is primarily responsible for causing problematic damage and will be discussed throughout the rest of this section. NPTM adults are small moths (>1/2 inch wingspan) with a mix of shiny gray, cream, and copper colors (Figure 13, pg 98). Eggs are laid on pine needles, and once they hatch, the small cream-colored larvae begin feeding on the outside of needles. This larval stage that feeds on the outside of the plant is targeted for contact insecticides, and applications must be timed to coincide with this life stage. As larvae mature, they darken to a light brown color and begin to bore into pine buds and stems (Figure 14, pg 98). Contact insecticides will not be effective once larvae are protected within the pine tissue. There are 2 - 5 NPTM generations a year in Georgia, depending on the location.

Loblolly, Virginia, and shortleaf pines are the species most susceptible to NPTM damage, however, other species may be attacked. NPTM can cause economic damage in Christmas tree farms, pine nurseries, and younger pine stands with trees generally less than 5 years old or 9 feet tall. While tree mortality is rare, infestations can cause shoot mortality, volume losses, and stunted or deformed trunks. There is some uncertainty as to whether NPTM-induced damage reduces tree growth gains to a degree that is felt throughout the 20+ year life of the stand. Making appropriate management plans for NPTM can be difficult due to this uncertainty, difficulty in timing insecticide applications, and lack of information on financial tradeoffs of applying an insecticide.

In the past, using insecticides for NPTM suppression was most common in Christmas tree farms, seed orchards, nurseries, and on research plots. As pine management has intensified, NPTM control is more important to growers. Contact insecticide sprays may be applied using spray timing recommendations, trapping, or monitoring to determine spray timing. In recent years using systemic insecticides at planting has become a management option.

Weevils

Weevils or snout beetles are a diverse and abundant group of beetles that can be pests in agriculture, horticulture, and forestry. Adult weevils are distinguished by their long hardened "snout".

Larvae are creamy-white with brown head capsules. Many different weevil species can cause damage to forest trees and tree nut crops, but two weevil species cause most damage by boring into tree tissues – white pine weevil (*Pissodes strobi*) and the deodar weevil (*Pissodes nemorensis*).

WHITE PINE WEEVILS kill the tops of conifers – mostly the top 1 – 2 feet (Figure 15, pg 99). Their damage is most troubling for white pines in Georgia. White pine weevils attack conifers greater than 4 - 5 years old and more than 3 feet tall, causing growth losses. Trees are rarely killed, but they can develop a deformed, bushy appearance.

Adult white pine weevils are brown with irregular gray-white and rust colored patches and are up to ¼ inch long. Adults emerge in the spring and begin feeding on conifer stems near the terminal bud (leader). Females create pits on the terminals and lay eggs.

Pitch will flow from these pits, which is the first sign of white pine weevil infestation. Larvae tunnel downward and around the stems, girdling the leader. Leaders begin wilting, growth is stunted, and the leader eventually dies. Pupation occurs in the stems, and adults emerge during summer. They then overwinter as adults. There is one generation a year. Infested trees are left with dead terminals, numerous lateral branches growing to take over as the leader, and ultimately, a crooked or forked stem.

White pine weevil management practices:

- Plant white pines with hardwoods or under hardwood cover.
- Plant on soils where the hardpan is 3+ feet below the soil surface.
- Prune away and burn the damaged shoot and prune so that only one lateral shoot attains dominance.
- Apply approved contact insecticide sprays to the top two feet of the leaders as adult weevils emerge to reduce damage occurrence.

DEODAR WEEVILS attack many species of southern pines and introduced cedars. Stressed and dying trees are most susceptible to deodar weevil attacks. Deodar weevils are active during the fall and winter, whereas most other pine pests are active during warmer temperatures. A fading crown during cooler temperatures is a sign of possible deodar weevil infestation. The most distinctive sign is the presence of chip cocoons under the bark, which are little wood chip cocoons that larvae create for pupation (Figure 16, pg 99).

Adults emerge in the spring and are inactive during warmer weather (Figure 17, pg 99). Adult color ranges from gray-to-reddish-brown with white patches and spots. They become active, feed, and lay eggs in the fall. Females lay eggs in the inner bark of trees, and once the larvae hatch, they begin feeding under the bark, which girdles the tree. Larvae build their chip cocoons during late-winter into early spring and begin pupating. Pine crowns will begin fading, and bark can slip off of the trunk in heavy infestations. In addition to attacking stressed trees, deodar weevils may reproduce in slash. The best management tactic to reduce deodar infestation risk is to maintain healthy pine trees. Since deodar weevils attack stressed trees and feed under the bark, insecticides are not an appropriate management tactic.

Wood Boring Beetles

Wood boring beetles are from two families of beetles: Cerambycidae and Buprestidae. Ceramycid beetle adults are called long-horned beetles due to their long antennae. The larvae are called round-headed wood borers and have a cylindrical shape. Buprestid beetle adults are called metallic wood borers, have a metallic color on part or all of their bodies, and have a tapered abdomen. Larval buprestids are called flat-headed wood borers because of the shape of the exit holes the insects make when they emerge from trees.

Wood borers feed under the bark and then can bore into the sapwood and heartwood. Buprestids create oval shaped tunnels, while cerambycids generally create round tunnels. It can take from one year to multiple years for boring beetles to complete their lifecycle. There are many species of native wood borers that attack trees, and each species will attack either conifers or hardwood trees. Native wood borers usually attack dead or weakened trees and can even be found emerging from firewood. As with bark beetles, maintaining healthy trees is the best way to prevent native wood boring beetle infestations. Unfortunately, there are two invasive wood borers that are currently threaten Georgia's trees: the emerald ash borer (Buprestidae) and the Asian longhorned beetle (Cerambycidae).

EMERALD ASH BORER (*Agrilus planipennis*) (EAB) is an invasive wood boring beetle that feeds on all ash species and was first detected in the United States in 2002 in Michigan. At the time of publication, the EAB range has expanded throughout the eastern US and as far west as Colorado. It was detected in Georgia in 2013 and has spread to many counties in the northern part of the state.

EAB adults have a metallic emerald green body (Figure 18, pg 100), and the larvae can grow as long as 1.3 inches and are creamy white. It generally takes one year to complete their lifecycle, but it can sometimes take two years. Adult beetles emerge in the late-spring and feed on ash leaves for a few weeks before laying eggs. Eggs are deposited on bark crevices, and the larvae hatch and chew into the phloem and cambium of the ash trees. Larvae create S-shaped serpentine galleries that widen as the larvae grow (Figure 19, pg 100). EAB overwinters as a prepupae and emerge from the tree as adults.

EAB attacks healthy ash trees and is decimating ash populations in many states. Signs of EAB infestation include a thinning ash crown, epicormic shoots, blonding (patches of missing outer bark from woodpecker feeding), and serpentine galleries under the bark. There are insecticide options for managing EAB and protecting ash resources (see resources in Table 2, pg 34).

ASIAN LONGHORNED BEETLE (*Anoplophora glabripennis*) (ALB) was first established in the US in 1996 in New York. It has been documented in six states and has been successfully eradicated from three of those states at the time of publication. In 2020 ALB was first observed in South Carolina. This is the first documentation of ALB in the southeastern US. ALB is a regulated invasive insect. The USDA Animal Plant Health Inspection Service (Plant Protection and Quarantine Unit), as well as the Georgia Department of Agriculture and Georgia Forestry Commission, may enact quarantines which place restrictions on moving wood products and nursery stock. Check with the Georgia Department of Agriculture and Georgia Forestry Commission for updated information on invasive species quarantines in Georgia.

ALB feeds on maples, willows, elms, birch, poplars, and additional tree species. ALB adults are black beetles with white or yellow spots and long black and white banded antennae (Figure 20, pg 100). Adults are from 0.75 – 1.5 inches long. Larvae are yellowish-white and can grow up to 2 inches long. ALB females lay eggs in the spring – summer, and larvae feed in the tree for numerous months. The lifecycle can be one or two years, depending on climate.

Signs of ALB damage are dead branches, boring dust at the base of the tree, 0.4-inch exit holes (Figure 21, pg 100), galleries under the bark and tunnels in the wood. Management tactics include preventative systemic insecticide applications and removing damaged and dead trees to prevent infestations of adjacent of nearby susceptible trees. Eradication programs have been successful by removing not only infested trees, but high-risk host trees in a buffer area around the ALB infestation. Please contact the Georgia Forestry Commission if you suspect an ALB infestation.

Chewing Insects

The chewing insects grouping consists of insects that feed on stems and shoots, specifically reproduction weevils. It does not include leaf-eating insects or borers,which are covered in other sections.

REPRODUCTION WEEVILS – There are two problematic reproduction weevil species in the Southeast, the Pales weevil (*Hylobius pales*) and the pitch-eating weevil (*Pachylobius picivorus*). Reproduction weevils feed on young pines of all southern pine species. Pales weevil adults are 1/4 - 1/3 inch in length, are black to reddish brown, and have patches of yellow hairs on the hard-outer wings (elytra). Adult pitch-eating weevils are 1/3 – 1/2 inch long with yellowish spots on the elytra. Larvae of both species have a typical weevil larvae appearance: C-shaped with whitish color and brown heads.

Adult weevils feed at night and seek refuge in leaf litter during the day. They feed by stripping the bark off of seedlings and small twigs and stems of young pines (Figure 22, pg 101). Reproduction weevil damage kills seedlings and twig tips by girdling them. They also will feed on the inner bark of stumps and trees. Larvae create tunnels in the roots as they feed on xylem and phloem. Pupation occurs in chip cocoons located in the sapwood or bark of tree roots. They overwinter in the adult stage and emerge in the spring to begin feeding on trees, with most damage occurring in the spring and fall. Reproduction weevils can have two or more generations each year in the Southeast.

Reproduction weevils can largely be managed by the timing of harvest and subsequent replanting. If a stand is cut in the winter or spring, then the reproduction weevils will be mostly gone by planting time the next winter. However, when stands are cut in the summer or fall, then the weevils will still be onsite and will attack newly planted seedlings. If a stand is harvested after June, then growers should skip replanting that next winter,i.e., wait a year to replant. Insecticide treatments may be necessary to protect seedlings if planting is not delayed after a summer or fall harvest. See the current Georgia Pest Management Handbook for specific insecticide guidance.

Defoliating Insects

Defoliating insects eat leaves, including conifer needles. Caterpillars, sawflies, leafcutter bees, ants, beetles, and walking sticks are all defoliators. Damage from defoliators includes missing leaves, bits of missing leaf tissue, skeletonized leaves, and tunnels or odd blotches on leaves. When leaves are damaged or entirely removed, photosynthesis is reduced. The effect of defoliator damage depends on the degree of damage, time of year, tree species, and if the tree is affected for multiple years. Most hardwoods can tolerate mild to severe defoliation if it occurs once, especially later in the summer and fall. Defoliation numerous years in a row can be more problematic for tree health. Conifers can be more negatively affected by defoliation than hardwoods. Often defoliation damaged is noticed once the damage is fairly advanced, making control tactics, if warranted, difficult or unfeasible.

GYPSY MOTH, also called European gypsy moth (*Lymantria dispar*) is a moth that is native to Europe. (Note: At the time of publication, the Entomological Society of America is seeking a new common name for *L. dispar*. The common name “gypsy moth” will likely phase out in upcoming years.) *L. dispar* is a regulated invasive insect. The USDA Animal Plant Health Inspection Service (Plant Protection and Quarantine Unit), as well as the Georgia Department of Agriculture and Georgia Forestry Commission enact quarantines on regulated insects. *L. dispar* quarantines place restrictions on moving outdoor household items without removing all life stages of gypsy moth. It was brought to Boston, MA by an amateur entomologist and escaped into the environment in 1869. *L. dispar* has now established in Canada, the northeastern US, many Lake States, and as far south as North Carolina. It has been detected in many other states, although the populations have not been established.

Female adult *L. dispar* are white with a 2-inch wingspan and a heavy abdomen (Figure 23, pg 101). They are flightless due to the size of their abdomen relative to their wing size. Male adult L. *dispar* are dull brown and have a 1.5-inch wingspan. The egg phase is the longest life stage of the *L. dispar* lifecycle, lasting from mid-summer until early-spring in more southern areas. Females lay egg masses on tree trunks, branches, vehicles, firewood, tables, and many other outdoor surfaces. *L. dispar* can be spread when people unknowingly move objects with egg masses. *L. dispar* caterpillars can grow up to 2.5 inches long and have three pairs of blue spots and five pairs of red spots on their back (Figure 24, pg 101).

L. dispar caterpillars defoliate many tree species, including oaks, willows, sweetgum, witch-hazel, and river birch to name a few. Caterpillars are active in the spring, which is detrimental because this is a very active time for foliage growth. Trees that loose over 50% of their canopy must use their stored reserves for energy while regrowing new leaves (refoliation), which strains the tree. Healthy trees can survive defoliation; however, repeated defoliation can kill trees. Defoliation can weaken trees and make them more susceptible to other biotic and abiotic stressors. In addition to tree health problems, *L. dispar* can be a nuisance. Defoliation can reduce aesthetic appeal, and caterpillars leave a large amount of solid waste (frass). Frass covers outdoor surfaces, which is unpleasant for residents and tourists in public areas.

L. dispar range expansion has been slowed due to a comprehensive federal and state collaborative program called the "Slow the Spread Program" that started in 1999. The program involves monitoring for *L. dispar* using pheromone traps, determining new population boundaries, and eradicating populations in new areas. Eradication tactics include using mating disruption chemicals and the bacterial pesticide *Bacillus thuringiensis* var. *kurstaki* (abbreviated Btk), which affects the digestive system of caterpillars. The "Slow the Spread Program" has reduced the spread of *L. dispar* by 60%. Please contact the Georgia Forestry Commission if you suspect a *L. dispar* infestation in your area.

SAWFLY larvae of many species can cause problematic tree defoliation, especially in planted pine stands. Sawflies are primitive stingless wasps. The adults have a broad waist and a saw-like ovipositor, which is an organ for laying eggs. Sawfly larvae look similar to caterpillars. However, sawfly larvae are usually hairless and have fleshy prolegs on every abdominal segment. Caterpillars do not have prolegs on every abdominal segment and have hairs on their body. Common sawfly species on pine have larvae that range from 2/3 – 1-1/4 inches long. Their color can vary from a creamy white to dusky gray, and they often have stripes or spots, depending on the species.

Females use their saw-like ovipositor to make slits in pine needles to deposit eggs. Larvae hatch and feed on needles. Often, they feed in groups, stripping all of the needles from a branch. They occasionally have outbreaks, which result in growth losses and tree mortality. Sawflies, depending on the species, may have 2-3 generations a year.

The redheaded sawfly (*Neodiprion lecontei*) (Figure 25, pg 102) and blackheaded sawfly (*Neodiprion excitans*) (Figure 26, pg 102) are more commonly found in the Southeast. However, numerous other native pine sawflies can be damaging. Insecticide control may be necessary during outbreaks. Insecticides will be most effective early in an infestation when larvae are smaller. Insecticide treatments are more feasible for smaller trees.

PINE WEBWORM (*Pococera robustella*) is often first noticed by the nests of mature larvae. The nests are constructed of coarse larval frass pellets, pine needles, and silk webbing (Figure 27, pg 102). Larvae feed on needles protected within their nest. Nests can range from 1 – 6 inches long and may host numerous caterpillars. Pine webworms can have one to three generations per year, depending on the geographic location. Females deposit eggs on pine needles and young larvae mine into needles. Mature larvae are 1/2 – 2/3 inches long with a light brown color and dark brown longitudinal stripes (Figure 28, pg 102). Larvae clip needles and bring them into the nest to eat them.

Smaller seedlings are more susceptible to pine webworm damage, including occasionally complete defoliation. Insecticide control is usually not necessary. Because older larvae feed in a protected location, effectively spraying contact insecticide can be difficult.

FALL WEBWORM (*Hyphantria cunea*) are most noticeable by their glistening webs in tree canopies (Figure 29, pg 103). These native insects can feed on more than 400 tree and ornamental species and have a range throughout the contiguous US. Common hosts are maple, sweet gum, pecan, hickory, walnut, and persimmon.

In the south, fall webworms can have up to five generations each year. Females lay eggs on the undersides of leaves in the spring. Caterpillars begin feeding on leaves and build a silken webbed nest that encloses foliage. As the caterpillars grow their nest size increases. They leave the nest to feed at night, resulting in defoliated areas of canopy outside of the nest.

Larvae are hairy with a yellowish-greenish body that may darken over time. There are red-headed and black-headed larval color forms (Figure 30, pg 103). Adult wingspan is 1-1/2 to 1-2/3 inches, and they are white and may have dark brown wing spots depending on the color form.

Fall webworm damage is mostly aesthetic, due to the nests being visually unpleasant to homeowners. Damage to trees in forests is often not a major issue, because healthy deciduous trees can tolerate occasional defoliation, and insecticide control is not needed. However, pecan production trees may warrant fall webworm management.

OAKWORMS, three species of which can cause tree damage in Georgia: orange-striped (*Anisota senatoria*), spiny (*Anisota stigma*), and pink-striped (*Anisota virginiensis*) oakworms (Figure 31, pg 103). Orange- striped oakworms when mature are black with narrow orange longitudinal stripes and black spikes. The spiny oakworm is brownish with an orange-brown head, black spines, and white dots. Pink- striped oakworms are greenish-brown with longitudinal pink stripes and black spikes. All species have a pair of long, curved spines called “horns” behind their head.

There is usually one generation each year, with peak defoliation occurring in late-summer to early-fall. Larvae can quickly strip the foliage from an oak tree and produce a large quantity of fecal pellets, which is distasteful in residential areas. The impact to tree health is generally not problematic, since damage occurs later in the season when trees are about to lose their leaves. Insecticide control in forests and most residential settings is not recommended.

Sucking Insects

Sucking insects are from the order Hemiptera and are considered to be "true bugs". They have piercing-sucking mouthparts that are similar to a straw. They use their mouthparts to pierce plant tissues and suck sap from the plant. The feeding activity from these insects can cause multiple symptoms on trees: leaf discoloration, curled foliage, leaf drop, branch mortality, galls, and honeydew and sooty mold on and under the plant. There are many sucking insects that damage trees, including scales, aphids, adelgids, lace bugs, stink bugs, whiteflies, etc. A few examples are discussed in the text below.

LACE BUGS (*Corythucha* species) feed on the undersides of leaves of many tree species. Adults and nymphs feed by piercing the leaf surface and sucking plant fluids. Lace bugs have multiple generations each year. Different life phases co-occur on leaves. Adults are small (approx. 1/4 inch) and have wide, transparent lace like wing covers that may be marked with dark spots (Figure 32, pg 104).

Nymphs are wingless, dark colored, and spiny. Adults, nymphs, frass, and white cast skins (old exoskeletons) are all visible on the undersides of leaves.

While they are present on the underside of leaves, their damage is noticeable on the upper leaf surface. Chlorotic spots are yellowed areas that mark where their mouthparts have pierced the leaves. These spots give the leaves a yellowed mottled appearance, and heavy feeding causes the leaves to appear faded out due to the many chlorotic spots. Heavy damage can cause premature leaf drop, but feeding does not typically harm the tree unless there is severe damage for numerous years. Healthy trees can withstand lace bug feeding. Damage is often most apparent in late-summer to early-fall, as population levels have increased over the growing season. Natural enemies keep lace bug populations under control in forest settings. Chemical control is rarely needed.

SCALE INSECTS can be pests in forests and trees, including pine needle scale (Figure 33, pg 104), elongate hemlock scale, pine tortoise scale, lecanium scales, tulip tree scale, etc. There are over 1,000 species of scale insects in North America. Adult females are wingless, often legless, and most are sessile, meaning they settle in one place and do not move. Adult males are winged, mobile, and do not feed on plants. Females lay eggs under their bodies, and once hatched, the nymphs or “crawlers” move to find a feeding location. Generally, scales are divided into armored scale and soft scales.

Armored scales are small (1 - 3 mm), have numerous generations per year, and are covered with a protective covering of wax and skins from past growth stages. They do not excrete honeydew because they feed mostly by breaking and feeding on plant cells, and often bypass the vascular tissues. Armored scale control can be difficult for the adult phase because they are protected by their waxy covering.

Soft scales do not secrete waxy armored coverings but may have a smooth, waxy, or cottony covering. They are 2 - 6 mm long and can be flat to almost spherical. Some adult female soft scales keep their small legs and can move very slowly. Soft scales often have only one generation a year, feed directly from vascular tissue, and secrete honeydew, which is a sugary solution. Blackish sooty mold grows on the honeydew that has fallen on the ground and plant tissues. The sooty mold is often the most obvious sign of scale insects. Soft scale infestations can be easier to detect because of their larger size and the presence of sooty mold.

There are many different scale insects, and there can be a great deal of variation in lifecycle and damage habits. It is essential to determine the scale species to inform management decisions. In general, crawlers are most susceptible to chemical control, since a waxy covering is not present to protect them. Not all insecticides are effective against scale insects. Read the labels carefully to ensure correct product usage.

APHIDS are one of the most common insect pests on trees (Figure 34, pg 104). There are hundreds of aphid species in North America, but most species do not cause economic problems. These small (> 1/5 inch) insects suck plant sap and have multiple generations per year with rapid reproduction rates. They have a soft, oval-shaped body with cornicles (little stem-like structures) sticking backwards from their hind end. Aphids have variable colors ranging from light green to dark brown to orange. Woolly aphids have waxy fibers that cover their bodies. Aphids can be either winged or wingless, most are female, and lifecycle varies among different species.

High aphid populations for an extended time can cause leaf wilting, leaf curling, and shoot and bud dieback. Aphids also produce honeydew, which results in sooty mold growth on plant tissues. Often the presence of sooty mold is more problematic than the aphid damage. Natural enemies, such as lady beetles and parasitic wasps, generally keep aphid populations in check. Aphids do not tend to cause problematic damage in forest settings. However, occasionally chemical control is necessary in high value trees, such as plant nurseries and Christmas tree plantations.

HEMLOCK WOOLLY ADELGID (*Adelges tsugae*) (HWA) was detected in eastern North America in the 1950s and in Georgia in 2002. HWA is an invasive insect from Asia that feeds on eastern and Carolina hemlock by sucking plant fluids. It is a small aphid-like insect with a woolly protective covering. An infested hemlock branch looks like it has little cotton balls that are adhered to the base of the needles on the underside of the branch (Figure 35, pg 104). These woolly masses are on the tree from fall to early-summer. HWA has a complicated life cycle with two generations a year, mostly female offspring, and a dormant time during the summer.

Unfortunately, HWA has killed millions of hemlock trees in eastern North America. Signs of HWA feeding includes: graying needles, dead branches starting on the outer part of the canopy, and tree mortality in as little as 2 – 4 years in the Southeast. Hemlocks are important species for wildlife and forest ecosystems, so their loss causes negative effects in forests.

Hemlock trees can be conserved with the use of systemic insecticides. Specific guidance is referenced in Table 2.

Table 2: Forest Insect Resources

Pest	Publication Name	Link
Southern pine beetle	Southern Pine Beetle: Biology, Prevention, and Restoration	https://gatrees.org/wp-content/uploads/2020/03/SPBBrochure.pdf
Ips engraver beetle	*Ips* Bark Beetles in the Southeastern US	https://sref.info/resources/publications/ips-bark-beetles-in-the-southeastern-u.s/at_download/file
Black turpentine beetle	Featured Creatures: Black Turpentine Beetle	http://entnemdept.ufl.edu/creatures/trees/beetles/black_turpentine_beetle.htm
Nantucket pine tip moth	Nantucket Pine Tip Moth: An Insect Pest of Young Pine Stands	https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-19-34_McCarty.pdf
White pine weevil	White Pine Weevil: Insect Notes	https://content.ces.ncsu.edu/white-pine-weevil-1
Deodar weevil	What is Attacking my Pine? The Case of the Deodar Weevil	http://extension.msstate.edu/sites/default/files/publications/publications/P3057.pdf
Emerald ash borer	GFC EAB Resources Insecticide Options for Protecting Ash Trees from Emerald Ash Borer	https://gatrees.org/emerald-ash-borer-eab/ http://www.emeraldashborer.info/documents/multistate_eab_insecticide_fact_sheet.pdf
Asian longhorned beetle	Asian Longhorned Beetle *Anoplophora glabripennis*	https://bugwoodcloud.org/resource/files/16644.pdf
Gypsy moth	Gypsy Moth in Georgia Gypsy Moth in the Southeast	https://gatrees.org/gypsy-moth-in-georgia/ https://www.fs.usda.gov/treesearch/pubs/53818
Sawflies	Pine Sawflies	https://entomology.ca.uky.edu/ef410
Fall webworm	Fall Webworm Outbreaks	https://www.warnell.uga.edu/research/news/fall-webworm-outbreaks
Oakworms	Hardwood Defoliating Caterpillars of North Georgia	https://gatrees.org/wp-content/uploads/2020/02/Hardwood-Defoliating-Caterpillars-of-North-Georgia.pdf
Hemlock woolly adelgid	Hemlock Woolly Adelgid Management in Georgia GFC HWA Resources	https://www.warnell.uga.edu/sites/default/files/publications/WSFNR-19-41_McCarty.pdf https://gatrees.org/hemlock-woolly-adelgid-hwa-in-georgia/

DISEASES

Disease prevention in forests is more effective than attempting to manage a disease after it causes damage. There are no pesticide cures for forest diseases, only a few preventative treatments. After a disease is present in a stand, management options are limited to either accepting losses or reducing further losses. Management to prevent forest diseases depends on understanding the pathogens, the impact on hosts, and what conditions favor them. In the case of some exotic pathogens, control options are limited to slowing the spread and developing disease-resistant trees over time.

Root/Butt Diseases

Root and butt diseases progress slowly, causing symptoms and losses in scattered trees or small groups of trees over time. The first symptoms of root disease are typically a thinning crown and chlorotic foliage. In some cases, a windthrown tree will be the first indication a root disease is present (Figure 36, pg 105). Native bark beetles, such as *Ips* and black turpentine beetles, typically attack trees affected by root disease. Native pathogens that cause root and butt rots are common in old growth forests and are a natural part of the forest ecosystem; however, significant losses to root diseases can occur in young stands under certain environmental conditions and management decisions.

HETEROBASIDION ROOT DISEASE: In the South, Heterobasidion root disease (syn, annosum root disease) is caused by *Heterobasidion irregulare* (syn. *H. annosum*). All southern pines are hosts for this pathogen that can cause root rot, butt rot, reduced growth, and mortality. The incidence of Heterobasidion root disease is greatest in thinned pine plantations on high-hazard sites of sandy, well-drained soils that are 12 inches or greater in depth. Although all pines are susceptible to this disease, loblolly pine has been found to be twice as susceptible as longleaf pine on these high-hazard sites. The disease is also associated with thinned eastern white pine stands and recreation areas in the Appalachian Mountains.

Conks, fruiting structures of the pathogen, are produced during cool wet weather when the mean daily temperature is less than 70°F (21°C). The conks typically occur at the base of infected trees or stumps and produce spores that can spread long distances. Pine stands become infected by windblown spores landing on fresh cut stumps or wounds exposed for less than 12 - 14 days. Spores can also percolate through sandy soils when the organic layer of soil is removed during thinning operations and directly infect roots. Freshly cut stumps are the principal (90%) entry point for Heterobasidion root disease within a pine stand. The disease spreads though root contacts to healthy adjacent trees. Signs and symptoms of root disease will not begin to show in a stand until 2 - 4 years after thinning or wounding. Pockets of Heterobasidion root disease can expand in the South up to 10 years.

Heterobasidion root disease can be identified by the conk (Figure 37, pg 105); however, conks are annual and often not present. Foresters should examine the roots of symptomatic trees for resin-soaking or white-stringy rot that often leads to windthrow (Figure38, pg 105).

Pine stands located on high-hazard sites have a greater probability of significant losses to Heterobasidion root disease and should be managed for disease prevention. Stands located in the southern half of the state (below the 34°N latitude) can be thinned without a stump treatment in the summer when spores are low. If a high-hazard site is to be thinned in the winter, then a stump treatment is strongly recommended. Eastern white pine stands and recreation sites should always be managed for Heterobasidion root disease during thinning or partial cuts. A borate stump treatment, disodium octaborate tetrahydrate, seals the stump from infection and is used in stands where the disease is either not present or affects less than 10% of the stand. Another commercially available stump treatment uses the biological control agent, *Phlebiopsis gigantea*, that can be applied in first thinning and in stands affected by the disease that are to be partially salvaged. Once 40% of a pine stands root system is infected, or damages exceed tolerable loss, full harvest is recommended.

PHYTOPHTHORA ROOT DISEASES: *Phytophthora cinnamomi* is a nonnative pathogen introduced in the 1800s that has had a significant impact on forests in Georgia by causing ink disease of American chestnut and contributing to littleleaf disease of pines. In the Piedmont region, soils were heavily eroded from past farming leaving behind the finer-textured subsoil with poor drainage and fertility.

Soils with low permeability and prolong periods of high moisture provide a favorable environment for *Phytophthora* and the development of root disease. American chestnut is highly susceptible to *P. cinnamomi,* resulting in severe losses to this disease in the Piedmont. The American Chestnut Foundation and partners have included testing of blight-resistant American chestnut (hybrids) for *Phytophthora* resistance in the effort to reintroduce American chestnut to the Piedmont.

LITTLELEAF DISEASE of pine is caused by a complex of factors including low fertility, poorly drained clay soils, and Phytophthora root disease. Shortleaf pine has been severely affected by littleleaf disease throughout the Piedmont, significantly reducing its presence in the region (Figure 39, pg 106). Loblolly pine can also develop littleleaf disease but is less susceptible than shortleaf pine. Other southern pines are rarely impacted by this disease. Symptoms of littleleaf disease include fine root necrosis followed by thinning crowns, chlorotic short needles, and numerous underdeveloped cones (Figure 40, pg 106). The disease rarely affects stands under 20 years old. As affected stands age, the severity of the disease increases significantly. Trees damaged by littleleaf disease have reduced growth and can decline for 6 or more years before dying. Affected stands are also highly susceptible to attacked by bark beetles and can fail to reach rotation age. In stands with less than 25% littleleaf disease and adequate stocking of apparently healthy trees, removal of the diseased trees during thinning may be appropriate. Fertilization could be used if remaining trees are in good condition and the treatment is economically viable. In a heavily diseased stand or a stand that would be understocked if diseased trees were removed, management options include harvest and regeneration with less susceptible species, or regeneration with a seed or shelterwood cut if enough disease-free trees are present.

A Shortleaf Pine Initiative has been established by federal, state, and interested private groups to restore shortleaf pine throughout its range. A site suitability tool for shortleaf pine restoration to assist managers is available on shortleafpine.net. On site visits, a shovel can help a manager determine if soils are high hazard for littleleaf disease. High-hazard soils will be eroded (little to no topsoil), have high clay content, and very low permeability. Soils with poor drainage and prone to flooding, or with a high-water table, typically have moderate to strong mottling (grey and brown spots) of the subsoil. Soils best for shortleaf pine restoration have an organic horizon, topsoil with greater than 18-inch depth of good internal drainage, and low probability of flooding.

OTHER ROOT DISEASES and butt rots that occasionally cause stand damage included red root and butt rot (caused by *Onnia circinata*), brown cubical rot (caused by *Phaeolus schweinitzii*) of pines, and Armillaria root disease (primarily caused by *Armillaria mellea*) affecting many species. The pathogens that cause brown cubical rot and red root and butt rot are slow to develop and often require a decade to kill an infected tree. These root and butt rots are most often seen in old growth pine stands but have been noted in damaged pine orchards and urban trees (Figure 41, pg 106). Armillaria root disease is common on most tree species dying from other causes. Of the species found in the South, *A. mellea* is most virulent and is associated with oak decline.

Stem Cankers

Canker diseases of the stem are caused by pathogens that kill the phloem, cambium, and sapwood creating discolored, flattened, sunken, or even swollen areas on the stem. In general, the virulence of a pathogen dictates its importance. Weak pathogens will cause cankers on trees dying from other causes, such as drought, mechanical damage, other diseases, etc. A common example of a weak, secondary pathogen is *Biscogniauxia* (*Hypoxylon*) cankers on hardwoods. Virulent canker pathogens can cause wood degradation and tree mortality of relatively healthy trees, and therefore, pose a more serious problem. There are perennial cankers and galls that take decades to form a stem defect and eventual breakage, or diffuse canker diseases that girdle the stems leading to rapid mortality. The most famous example of a diffuse canker devastating a forest species is chestnut blight, caused by the introduced pathogen *Cryphonectria parasitica*, which functionally removed American chestnut from its natural range. Advances have been made to breed trees resistant to chestnut blight, and the effort to restore American chestnut to the landscape is becoming more likely.

FUSIFORM RUST, caused by *Cronartiium quercuum* f. sp. *fusiforme*, is the most economically important disease in the South. Rust incidence is greatest in young, vigorous plantations of slash and loblolly pine. Longleaf pine is much less susceptible to fusiform rust than loblolly pine, while shortleaf and Virginia pine are relatively resistant. The pathogen causes a perennial gall canker on main stems and branches that eventually becomes sunken and elongated over time (Figure 42, pg 107). The early development of fusiform rust cankers on seedlings and saplings often results in mortality or deformity (Figure 43, pg 107). Trees that reach maturity with a fusiform rust canker on the main stem are prone to wind breakage.

The disease cycle of fusiform rust takes two years and requires both pine and an alternate oak host. Oak hosts include water, laurel, turkey, willow, blackjack, bluejack, and southern red oak. In the early spring, spores produced on oak leaves infect pine needles and succulent stems. Initially, infected pine stems develop swellings that eventually become spindle-shaped, or elongated galls. In the spring, these fusiform galls will produce yellow to orange spores that infect oak leaves, thus completing the disease cycle.

Resistance breeding programs for loblolly and slash pine have been ongoing for 50 years, resulting in some level of resistance to fusiform rust in most available seedlings. The improvement of host resistance has decreased fusiform rust in plantations. However, there is still considerable variation in rust resistance and management of the disease is required. Control of fusiform rust begins in the nursery with fungicide treatments of seed and young seedlings to ensure they are rust-free prior to planting. In slash and loblolly pine plantations, rust incidence increases during the first 5 years with higher site indexes and intensive management. Upland sites with high oak populations also have a greater risk of fusiform rust. Managers can reduce fusiform rust incidence by use of improved rust-resistant seedlings or more resistant pine species on high-hazard sites. Young pine plantations between 3-5 years should be surveyed for stem galls. If rust galls are present on 50% or more of the stems, then the site should be rouged and replanted. Older stands affected by fusiform rust can be improved with selective thinning.

PITCH CANKER on pines is often identified by the copious amount of pitch oozing from infected, resin-soaked cankers or lesions. The pitch canker pathogen, *Fusarium circinatum*, affects most southern pines including slash, loblolly, and longleaf pine. All vegetative and reproductive structures can be infected by the pathogen, including branches, stems, roots, cones, and seeds. Outbreaks of the disease occur most often in young pine plantations, causing crown dieback, stem deformity, growth loss, and occasional mortality. In most cases, the affected stands recover from the branch dieback. However, sustained pitch canker damage to some pine stands is associated with a continuous point source of high nitrogen (e.g. poultry house vents). High nitrogen fertilization has been associated with pitch canker outbreaks, and fertilization of affected stands increases the disease incidence, canker length, and related mortality.

Pitch canker is often associated with insects, both as wounding agents and vectors of the pitch canker pathogen. Insects most associated with pitch canker include pine tip moths, southern pine coneworms (*Dioryctria spp*.), deodar (eastern pine) weevil, and needle midges (*Contarinia spp*.). Wounds caused by storm damage (e.g. hail, high winds) or mechanical damage (e.g. pruning, clippers, shakers) have also been associated with pitch canker occurrence. Spores of the pitch canker pathogen are produced throughout the growing season and can be moved by wind and rain, as well as insect vectors. Perennial cankers form on stems (Figure 44, pg 107), butts, and exposed roots once the disease is established. The pitch canker pathogen is often found to colonize fusiform rust galls attacked by southern pine coneworm. The combination of pitch canker and the fusiform rust gall increases the probability of stem breakage and mortality prior to harvest.

Management of pitch canker in plantations is minimal. Trees with pitch canker affecting the branches typically recover over time. Use of fertilizer in stands during a pitch canker outbreak would worsen the damage and is not recommended. In rare cases where a stand is affected by a consistent and permanent source of nitrogen, the stand is unlikely to improve and should be harvested. Trees that develop perennial cankers on the stems or butt/roots can be removed during thinning.

CALICIOPSIS CANKER, caused by *Caliciopsis pinea*, is part of an insect-pathogen complex associated with sapling mortality and bottom-up branch dieback of eastern white pine. The pathogen appears to colonize wounds created by the eastern white pine bast scale (*Matsucoccus macrocicatrices*) (Figure 45, pg 108). Caliciopsis cankers begin as small reddish-brown depressions, which develop black cushion structures with bristle-like black fruiting bodies (1 mm) and copious resin (Figure 46, pg 108). The bast scales infest the thin bark (<1 cm) portions of the tree where Caliciopsis cankers also tend to develop. The density of this insect-pathogen complex on saplings and mature tree branches can lead to numerous cankers, coalescing over time, resulting in girdling. Individual canker on tree stems often become internal necrotic inclusions as bark calluses over the canker, resulting in decreased wood quality. The presence of the insect-pathogen complex is greatest in natural regeneration under an eastern white pine overstory. Silvicultural practices to mitigate the disease require more research.

Foliage Diseases

Foliage diseases affect tree photosynthesis and can reduce the vigor of an affected tree if leaf and needle losses are significant over time. The causal agents of leaf diseases include fungi, bacteria, viruses, nematodes, and air pollution. Damage by foliage diseases is typically minor as trees will refoliate. If defoliation is severe and occurs for several years, affected trees become susceptible to secondary pests, such as Armillaria root disease and bark beetles.

ANTHRACNOSE is a common leaf and branch disease that affects many hardwoods. In the South, oaks and American sycamore are often observed affected by anthracnose, caused by species in the *Apiognomonia* (anamorph: *Discula*) genus. The impact of anthracnose on most hardwood trees is greatest in the early spring during cool and wet weather. Twig infections are particularly likely when temperatures drop to 50 - 55°F after bud break. Leaf infection is greatest during rainy spring weather when temperatures range from 60 – 73°F. The greatest damage occurs when leaves are new and young, resulting in irregular blotches between veins that can become completely blighted. As leaves mature, they become more resistant to anthracnose, and lesions appear as small spots. Anthracnose lesions typically have a center of tan, paper-like tissue, surrounded by a darker brown to purple outline (Figure 47, pg 108). Fine twigs can be infected directly or from a leaf infection. Fine branch dieback from anthracnose cankers can cause branch deformity and severe defoliation. Trees affected by anthracnose usually recover in the summer with a second flush of leaves.

In general, damage from most anthracnose diseases is minor and does not cause growth loss unless defoliation from anthracnose occurs yearly. Dogwood anthracnose is an exception to the general rule. The pathogen that causes dogwood anthracnose, *Discula* *destructiva*, is believed to be nonnative and has severely reduced flowering dogwood in the Appalachian Mountains (Figure 48, pg 108). Flowering dogwood in the understory or shaded areas with high moisture become heavily infected and can die within a few years. Trees in the open or on the forest edge develop lower branch dieback, stem cankers, and eventually die. Dogwood anthracnose is less destructive in the lower elevations and warmer areas of Georgia. A spot anthracnose, caused by *Elsinoe corni*, is also common on dogwood flowers and leaves during wet cool springs. Damage by this spot anthracnose is minor.

Management of anthracnose in natural forests is unnecessary, or impractical. Management of susceptible species in plantations could be important. American sycamore has been planted for pulpwood and biomass production in past decades. However, pressure from numerous diseases became problematic. Interest in American sycamore for biomass production and pharmaceutical uses is likely to encourage research and production of more disease resistant trees in the future. Besides planting disease resistant seedlings, preventative measures to reduce anthracnose in plantations would include wider spacing and orientation towards prevailing winds to quickly dry foliage.

NEEDLECAST disease of southern pines is caused by pathogenic fungi in several different genera, including *Ploioderma*, *Lophodermium,* and *Lecanosticta*. Needlecast pathogens infect new needles in the spring and summer; initially causing yellow, reddish brown to grey spots or bands. These pathogens can spread, coalesce, and kill the foliage. Symptoms of these needle diseases are greatest in the lower half of the crown, with needle tips turning brown and minor needle drop. During particularly wet springs and summers, severe infections can develop resulting in most of the mature needles turning yellow to brown by winter or spring. Needlecast can become epidemic in some years so that whole stands appear fire scorched (Figure 49, pg 109). Pine stands heavily affected by needlecast typically recover with only some mild growth reduction. Although tree mortality is not directly related to needlecast disease, severe needle loss in combination with other stress factors can increase the probability of beetle attack. Control of needlecast disease in forests is considered both cost-prohibitive and unlikely to have any real effect on survival or stand volume.

BROWN SPOT NEEDLE BLIGHT caused by *Lecanosticta acicola* (previously *Mycosphaerella dearnessi*) is a serious disease of longleaf pine seedlings during the grass stage. Spore production and infection of needles begins in the spring and accelerates during warm-wet weather (70 – 80°F). The initial infection appears as a yellow spot that develops into a brown band with black fruiting structures (Figure 50, pg 109). As the disease spots expand needles become girdled and eventually the entire needle will turn brown.

Yearly needle losses in heavily infected longleaf pine plantations or uneven-aged forests results in growth loss, delayed seedling growth, and mortality. Prescribed fire in these affected stands can significantly reduce the source of spores for several years and allow surviving seedlings to recover and begin height growth. Once seedlings grow out of the grass stage and begin rapid height growth, they are more resistant to brown spot needle blight. Regeneration practices that favor early emergence into height growth reduces the timeframe that seedlings are susceptible. Best management practices include quality disease-free seedlings (container or bareroot), proper site prep, minimal seedling storage, and control of competing vegetation.

Wilts

Wilt diseases are characterized as sudden wilting and browning of foliage followedby rapid tree mortality from pathogens affecting the vascular system. Wilt pathogens are typically vectored by insects that feed or oviposit on the host. Once a tree is infected, the pathogen can move through the xylem and spread to adjacent trees by root connections. The rapid wilt and mortality of infected trees are a result of a reduction in the translocation of water in trees during the growing season.

LAUREL WILT pathogen (*Raffaelea lauricola*) and its vector, redbay ambrosia beetle (*Xyleborus glabratus*), were introduced to the southeastern United States in the early 2000's. Redbay is highly susceptible to laurel wilt and has sustained high mortality rates as the disease has spread throughout its natural range. Laurel wilt is currently spreading northward by infecting sassafras. Other species in the Lauraceae family native to the United States, are also susceptible to laurel wilt (e.g. pondberry, pondspice, swampbay, northern spice bush, etc.).

Laurel wilt rapidly kills redbay and sassafras after the redbay ambrosia beetle bores into trees and deposits spores of the fungal pathogen present in their mouthparts. Infected trees develop dark streaks in the sapwood restricting the flow of water and causing crown wilt within weeks to a few months (Figure 51, pg 109). Redbay leaves turn brown and remain attached for months (Figure 52, pg 110), while sassafras becomes defoliated soon after leaves discolor and wilt. Although laurel wilt can spread through root systems, the disease is dispersed primarily by the redbay ambrosia beetle. The movement of infested wood is another way the disease can be moved long distances to new locations. There are no practical treatments for this disease. Efforts to reduce the spread of laurel wilt are primarily focused on restricting movement of potentially infected wood. Identification of redbay cultivars resistant to the laurel wilt pathogen is being pursued by researchers for future restoration of this species. Germplasm collection of sassafras, and other less abundant species in the Lauraceae family, has also begun for potential restoration efforts.

OAK WILT: Although oak wilt has never been confirmed in Georgia, the disease has been confirmed in Tennessee, North Carolina, and South Carolina in counties near the Georgia state line. This disease could become a future problem for Georgia landowners. The causal agent of oak wilt, *Bretziella fagacearum* (formerly *Ceratocystis fagacearum*), can infect all oak species, but has had the greatest impact in species from the red oak group (e.g. red oak, black oak, southern red oak, Texas red oak, etc.) and live oaks. White oak is considered more resistant to oak wilt.

Symptoms of oak wilt begin to show in the spring and summer following infection either by insect vectors or from spread through root grafts creating groups of dying trees. Dark streaks often form in the sapwood of infected trees along with a rapid reduction in the translocation of water. In the red oak group, foliage symptoms occur within weeks of infection, beginning at the top and spreading quickly through the entire crown. Symptomatic foliage often droops and can appear water soaked or have marginal browning that progresses towards the center of the leaf (Figure 53, pg 110). Infected oaks trees in the red oak group will shed leaves rapidly, resulting in both green and symptomatic leaves on the ground. Mortality from oak wilt in the red oak group typically occurs within 4 - 8 weeks. In live oak, the veins of symptomatic leaves turn yellow to brown, and the leaves discolor to a yellowish bronze. The tips of live oak leaves can also turn brown. The crowns of infected live oaks will thin as symptomatic leaves drop. Live oaks can die from oak wilt within 3 months to a year, while somelive oaks can take several years to die.

Oak wilt is spread overland primarily by sap-feeding beetles in the Nitidulidae family. Sap-feeding beetles are attracted to the fruity smell of fungal mats that form under the bark of recently killed trees primarily in the red oak group (Figure 54, pg 110). Pressure from the fungal mat causes cracks in the bark, allowing beetles to tunnel into and feed on the mat underneath. The beetles become contaminated with spores and transmit the spores to healthy oaks by feeding on the sap of fresh wounds.

Control of oak wilt is best focused on prevention, as the disease is difficult to manage once it is present. The best strategy is to avoid wounding potentially susceptible oaks in the spring when the spore mats are produced. Early detection of oak wilt will help limit its ability to spread. Consult forest disease specialists to confirm the presence of oak wilt and to advise on disease control options.

Table 3. Forest Disease Resources

Pest	Publication Name	Link
Heterobasidion Root Disease	Heterobasidon Root Disease In Eastern Conifers	http://southernforesthealth.net/news/new-heterobasidion-root-disease-fidl
Littleleaf Disease	Littleleaf Disease	http://southernforesthealth.net/diseases/littleleaf-disease https://www.fs.fed.us/foresthealth/docs/fidls/FIDL-20-LittleleafDisease.pdf
Other Root Diseases	Wood Decay	http://fungimag.com/winter-2018-2019-articles/Wood%20Decay.pdf
Fusiform Rust	Fusiform Rust	https://www.forestpests.org/georgia/fusiformrust.html https://www.fs.fed.us/foresthealth/docs/fidls/FIDL-26-FusiformRustSouthernPines.pdf
Pitch Canker	Pitch Canker of Southern Pines	https://www.fdacs.gov/content/download/11308/file/pp302.pdf https://www.forestpests.org/gfcbook/pitchcanker.html
Caliciopsis Canker	How To Look For White Pine Bast Scale And *Caliciopsis pinea*	https://forestrynews.blogs.govdelivery.com/2021/01/05/how-to-look-for-white-pine-bast-scale-and-caliciopsis-canker/
Anthracnose	Anthracnose Diseases of Hardwoods	https://extension.uga.edu/publications/detail.html?number=B1286&title=Key%20to%20Diseases%20of%20Oaks%20in%20the%20Landscape#anthracnose https://www.fs.fed.us/foresthealth/docs/fidls/FIDL-133-AnthracnoseHardwoods.pdf
Dogwood Anthracnose	Dogwood Anthracnose and Its Spread In the South	https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5447373.pdf
Needlecast	Pine Needlecast	http://www.state.sc.us/forest/pubs/pineneedlecast.pdf https://www.fdacs.gov/content/download/11394/file/pp388.pdf
Brown Spot Needle Blight	Brown Spot Needle Blight	https://forestry.ces.ncsu.edu/2019/02/forest-health-spotlight-brown-spot-needle-blight/
Laurel Wilt	Laurel Wilt	https://gatrees.org/wp-content/uploads/2020/02/Laurel-Wilt-USFS-Pest-Alert-2019.pdf
Oak Wilt	Key to Diseases of Oaks in the Landscape: Oak Wilt	https://extension.uga.edu/publications/detail.html?number=B1286&title=Key%20to%20Diseases%20of%20Oaks%20in%20the%20Landscape#anthracnose

VERTEBRATE PESTS

Several kinds of mammals and two kinds of birds sometimes damage living trees in the South, and damage varies from trivial to serious. The mammals: deer, hogs, rabbits, squirrels, and other rodents - are the most serious pests. Mammals will often select plant materials that have been fertilized if available, as well as those with a high moisture content. Periods of drought may intensify the damage of certain rodents, when they may eat bark for moisture. Some of these animals are protected as game animals, and permits are required to kill these animals outside of normal hunting season and bag limits. Check state and local regulations before acting.

Deer

The most serious deer damage occurs from browsing on seedlings in nurseries and in young plantations. This browsing may influence seedlings in numerous ways, ranging from poor formation and suppression of seedling height to providing access for disease or insect infestation that leads to increased mortality. Deer frequently damage saplings by rubbing them with their antlers (Figure 55, pg 111). This rubbing behavior, which may remove the bark, is usually associated with the breeding season in the fall and early winter. Damage may be reduced with chemical repellents or eliminated by excluding deer with suitable fences. Shooting can reduce deer numbers in damage areas. However, deer are protected game animals, and a permit is required to shoot depredating deer when the hunting season is not open.

Feral Hogs

Feral hogs, also known as wild pigs, Eurasian boar, or feral swine, are an invasive species that is rapidly increasing in abundance and distribution across North America. The species can multiply faster than any other large mammal. They can begin breeding at 8 months of age and can produce two litters of 4 - 12 piglets every 12 - 15 months. Feral hogs can do significant damage to a variety of forest systems. Hogs may damage or kill both hardwood and pine trees of all age classes. Hogs may prevent regeneration of masting trees through high consumption of their hard mast crops. Hogs will also damage seedlings by uprooting plants, consuming the soft roots, and exposing roots to fungal diseases. Hogs commonly rub and scent mark on mature trees, which can lead to damage to tree bark and possible girdling (Figure 56, pg 111). Trapping is the most effective approach for removing feral hogs and should focus on the removal of whole family groups, referred to as a pig sounder. Hunting, shooting at night, or hunting with dogs are rarely effective at removing sufficient numbers of hogs from the landscape to control their population.

Rabbits

Rabbits commonly found in the Southeast include eastern cottontail, marsh rabbits, and swamp rabbits. Many vegetation types throughout the Southeast support at least one species of rabbit. Rabbits prefer brushy vegetation that offers ample cover for hiding. Rabbits can damage well-established forest trees by girdling them, however, it is uncommon. Rabbits may, however, cause considerable damage to nurseries and portions of newly planted stands by nipping off seedlings. Rabbit cuttings look different from deer browsing because the cut edges are smooth, as if done with a knife, and often angled. Deer have only lower front teeth and must pinch and pull stems, which leaves a broken and ragged appearance. Chemical repellents can stop rabbit damage temporarily. Thirty-inch-high woven mesh fences will exclude rabbits from nurseries. Box traps and shooting (if permitted) can temporally reduce rabbit numbers in damage areas. Habitat modification can provide long-term, non-lethal control of rabbits. Removing brush-piles and other sources of cover may be effective in reducing high rabbit populations. Because rabbits avoid open areas where they are susceptible to predation, mowing vegetation around tree plantings can reduce damage.

Tree Squirrels

Tree squirrels, including the gray squirrel and the fox squirrel, may cause damage to trees by chewing bark from trunks and branches. Fox squirrels are particularly likely to damage pines. This damage occurs sporadically and is associated with high populations of these animals. Squirrels have two breeding seasons per year. Their populations may have periodic highs and lows not associated with losses associated with hunting. Squirrels may also cause damage by feeding on pine cones in seed orchards. Intensive hunting can reduce squirrel damage in some cases where permitted.

Beaver

Beavers are probably the most serious animal pest of timber in the Southeast. Beavers construct dams, which flood forest land. Although beavers prefer woody species such as sweetgum, black gum, tulip poplar, and pine, they will eat the leaves, twigs, and bark of most woody plants. They also girdle stems and fell trees (Figure 57, pg 111). Beavers will travel >100 yards (90 m) from water to find food and dam building material. Persistent removal of beavers with appropriate traps, combined with destruction of dams, can effectively reduce beaver damage. (Before undertaking such control tactics, obtain appropriate permits.) Although beaver populations increase slowly due to their low reproductive rate (two young per adult female per year), check for beaver damage periodically and trap if active beaver sign in present.

Cotton Rats

Cotton rats have medium brown, grizzled fur and are about 8-10 inches long, including the tail. They often chew the bark from young pines up to a height of about 10 inches. Because the populations fluctuate greatly, damage is sporadic with most occurring during population peaks. Where damage does occur, it likely affects pine plantations under four years old. Since cotton rats prefer dense cover, keeping the area around the young trees clean through herbaceous weed control will help to reduce cotton rat problems.

Pine Vole

Pine voles are small, short-tailed brown voles about four inches long. Although they may occur throughout the Southeast, they are rare in many areas. However, local populations may explode and cause serious damage, especially to small trees in orchard and nursery plantings. They chew the bark from roots below ground and stems of saplings up to a height of about four inches. The use of rodenticides is the only approach currently available for controlling pine vole populations in commercial orchards and nurseries. As rodenticides are designed to kill mammals, applicators should take precautions to prevent accidental exposure to nontarget mammals including wildlife, people, and pets.

Pocket Gophers

Pocket gophers have a stocky body about 7-8 inches long, a large head, and an almost naked tail. The forefeet have long, heavy claws for digging. The burrows are often marked by sand mounds at the surface. Pocket gophers avoid heavy clay soils and wet areas. They can harm orchards and tree farms by clipping the roots of trees they encounter when digging, which can kill seedlings or small trees. Pocket gophers are not usually a pest in forest conditions. Various mechanical and chemical control options are available. Control options are best conducted during spring and fall when animals are most active near the surface.

Woodpeckers

Woodpeckers may peck holes in live trees. The yellow-bellied sapsucker makes a couple to a dozen or more concentric circles of small holes around many kinds of trees (Figure 58, pg 111). Although this may girdle the tree, it is rare. The bird returns periodically to freshen the holes and feed on the sap welled up in them. Some woodpeckers may create cavities in live trees; however, they prefer dead or diseased trees. The red-cockaded woodpecker (RCW), an endangered species, is a woodpecker of note. The species is typically found in mature, fire- maintained pine forests. It makes its nest by excavating a cavity in large, mature (>60- year-old) trees. In the majority of cases, woodpeckers will not do significant damage under usual forest conditions. More importantly, woodpeckers are protected by state and federal laws. It should also be noted that pine tree removal within RCW habitat may violate the Endangered Species Act, and you should contact the U.S. Fish and Wildlife for further guidance.

VEGETATION CONTROL

Weeds

Weeds are unwanted vegetation that interferes with land management objectives. They inhibit forest regeneration, survival, and optimum crop tree growth and development. Weeds compete with crops for moisture, nutrients, and sunlight. They can be classified as weed trees, brush, vines, and herbaceous weeds.

WEED TREES are undesirable hardwoods and conifer species. They include deformed and defective or undersized individuals of commercial, non-commercial, and invasive species. Large, poorly formed or "wolf" trees can occupy significant growing space within a stand. Weed trees reduce the economic value of otherwise healthy, desirable trees. They affect both small and commercial size trees within a stand.

BRUSH includes shrubs, small trees, and woody perennials. These prevent light from reaching tree seedlings and deprive even taller commercial species of water and nutrients. Brush interferes with natural regeneration or planting and can create a habitat for rabbits and rodents that may damage newly planted stands. Over time, a build-up of brush in the understory can pose a fire hazard to the tree stand.

VINES include greenbrier, English ivy, oriental bittersweet, winter creeper, Japanese honeysuckle, Virginia creeper, trumpet creeper, wild grapes, kudzu, and other plants with climbing or creeping stems. All of these grow well on good forest sites. They can drag down tree branches and crowns. Vines in the top or edge of tree crowns intercept sunlight and displace tree foliage, often affecting photosynthesis. Vines can also compete with crop trees for soil moisture and nutrients. Vines have vigorous sprouting habits and are some of the most difficult weeds to control. Kudzu is a serious weed pest in planted and natural stands and is a threat to young and mature stands. Repeated herbicide applications are essential for control. It spreads so rapidly it can take over the site again in 2-3 years if a single root crown is left alive (Figure 59, pg 112). Follow-up treatments must be made for one or more years after initial treatment. Its ability to resprout following treatment varies with the stand age, root size, and plant vigor. Old stands may resprout for several years.

HERBACEOUS WEEDS retard seedling growth in new plantations and natural stands. Tree seedlings competing with herbaceous weeds may develop poorly or die, especially during droughty first and/or second growing seasons. They also create favorable cover for tree damaging animals such as mice, gophers, beavers, and cotton rats. They pose the potential for loss of a new plantation by wildfire. Control herbaceous weeds with herbicides labeled for this forest use. In forest nurseries, seed orchards, and Christmas tree plantings, herbaceous weed control is critical. These high-value forest crops must be free of weeds to allow for proper growth and development.

Herbicides

Herbicides are chemicals that kill or suppress the growth of plants. Plants are controlled by herbicides that act on their physiology. Different herbicides, concentration rates, application methods, and equipment enable users to control targeted weeds without undue injury to desirable plants or the environment. Herbicides are registered for the specific forest uses and application methods for which they have been tested. Uses other than those indicated on the label are unlawful and may not provide the needed control. Off-label use can cause adverse effects to non-targeted species on- and off-site by drift or movement in soil and water. Furthermore, unauthorized use may pose a hazard to human health.

MODE OF ACTION

Herbicides may be broadly classified as (1) contact herbicides and (2) translocated (systemic) herbicides.

(1) Contact herbicides kill only the plant foliage to which they are applied. These herbicides are often non-selective, affecting most plant species whether woody or herbaceous. Their use is often referred to as "chemical mowing." Because roots and even larger woody parts are not killed, resprouting may occur, and control is often short-lived. Due to poor control, the currently labeled contact herbicides are rarely used in forestry. However, treatments to kill and dry vegetation to increase fuel loading for site preparation burning can be used.

(2) Translocated (systemic) herbicides are those that must enter and move within the plant to be effective. They move to sites where they disrupt certain physiological functions. This enables them to severely stunt or kill the plant. Most herbicides used in forestry, whether applied to foliage, soil, bark, or cut surface, are of this type. Some translocated herbicides work in more than one way. Some of these may also act as contact herbicides at higher concentrations because of the petroleum additives in the formulations.

PLANT ACTIVITY

Depending on the chemical molecule used in the product, herbicides affect plants in different ways. These different modes of action are not always apparent on the outside of the plant, but they have a major influence on the success (or failure) of a particular chemical and the ability to mix different products for greater efficacy. The following seven modes of action describe the different ways in which forest herbicides can affect and eradicate certain plants.

Examples of chemicals used in forestry work are given for each category:

(1) Cell Membrane Disrupter - Oxyfluorfen and Paraquat (Paraquat is not commonly used in forestry)

(2) Respiration Inhibitor – Monosodium acid methanearsonate; MSMA (selective post-emergent mostly used in cotton, golf courses, and rights-of-way)

(3) Photosynthesis Inhibitor – Hexazinone (Velpar L VU, Velpar DF VU, Pronone, Velossa), Simazine, Atrazine (Atrazine 4L, Atrazine 90DF)

(4) Growth Inhibitor – Pendimethalin (Pendulum 2G; not commonly used in forestry)

(5) Lipid Biosynthesis Inhibitor – (grass control herbicides) Fluazifop-P-butyl (Fusilade DX), Clethodim (Arrow 2EC, Envoy Plus)

(6) Synthetic Auxins - 2,4-D (Weedone, Freelexx), Triclopyr (Forestry Garlon XRT, Garlon 4ultra, Garlon 3A, Trycera, Vastlan), Fluroxpyr (Vista XRT, Flagstaff), Clopyralid (Transline, Stinger, Clopyralid 3, Clean Slate), Aminopyralid (Milestone)

(7) Amino Acid Synthesis Inhibitor – Imazapyr (Chopper Gen2, Arsenal, Polaris AC, Polaris SP, Rotary 2SL, Imazapyr 4SL, Habitat), Metsulfuron methyl (EscortXP, Patriot, MSM 60), Sulfometuron methyl (Oust XP, Spyder, SFM 75), Imazamox (Clearcast), Imazaplc (Plateau, Impose)

(8) Aromatic Amino Acid Inhibiting Herbicide - Glyphosate (Roundup Power Max, Accord XRT, numerous generics)

(9) Enzyme Inhibitors – Fosamine (Krenite S)

FACTORS AFFECTING CONTROL

Plants vary in their susceptibility to different herbicides. They absorb various compounds differently and have different abilities to detoxify the herbicide. Herbicides start breaking down at varying rates soon after application. This breakdown is caused by microorganisms, sunlight, and chemical reactions. Herbicides eventually lose all effectiveness.

Pesticide Application

The type of application and equipment to be used for a specific job will depend on a number of factors. Before making a pesticide application you should:

- know the pest(s) to be controlled;
- be familiar with pesticides available for use;
- determine if a Licensed or Certified Applicator is required;
- know the size of the area needing treatment;
- have accessibility to the area;
- identify the presence of sensitive areas (e.g. wetlands, streams, houses, etc.) and organisms (such as livestock, wildlife, and any threatened or/and endangered species);
- determine the appropriate application method;
- properly set up and calibrate the equipment to apply materials. (see Appendix A for more information);
- apply pesticides only under appropriate environmental conditions; and always read and follow label instructions;
- properly rinse and dispose (or recycle) the empty container per the label.

ENVIRONMENTAL CONCERNS

The forest manager must be aware of the risks and consequences of pesticide use and their application in and around forested environments. Use pesticides only when necessary to minimize pesticide impact in areas receiving direct application as well as non-target habitats and organisms, which are potential recipients of pesticide drift and runoff.

Before you apply a pesticide, consider these points:

1. Do not apply a pesticide in windy or rainy conditions when the chances of drift, foliage wash off, and soil runoff are high.
2. Choose an application method and a pesticide formulation that will minimize the potential for movement of the material to off-site locations.
3. Restrict or minimize the use of volatile pesticides on areas in or around sensitive non-target plants or animals, especially during hot weather.
4. Generally, liquid pesticides applied by broadcast methods are more subject to drift than are granular.
5. During liquid application, spray droplet size should be maintained within the recommended range for the proposed target and the application method to be used. In general, large spray droplet sizes (> 300 microns) reduce the potential for pesticide drift. Large droplets do not evaporate as quickly as smaller droplets, so more material will potentially be available to hit the target site, especially during hot, dry weather. However, target spray coverage is usually improved as droplet size decreases (up to a point) since there are many more small droplets than large droplets per given volume of spray material. Another drawback with large droplets is that they may bounce off of and not adhere to leaf surfaces, resulting in poor coverage and increased off-site contamination.

6. Use additives to minimize drift and enhance efficacy as appropriate.
7. Materials applied to the soil surface can be moved off-site through runoff.
8. Individual stem application of pesticides can reduce the possibility of non-target impacts of the pesticide.

Application Terminology

Terms commonly referred to when dealing with methods of applying pesticides in forestry include:

Application rate: The specific amount of pesticide applied to a treated acre or target system.

Broadcast: Uniform application to an entire area.

Banded: Application to a strip or band over or along each tree row.

Basal: Application to the lower portion of stems or trunks.

Cut surface: Application to a cut or incision in a tree or to a stump.

Desiccation: The "brown-out" or drying of vegetation by use of herbicides to aid in burning for site preparation.

Directed: Aiming the pesticide at a specific portion of a plant (usually the foliage of the vegetation to be controlled, keeping herbicide off desired plants).

Dormant spray: Application before buds open in the spring or after trees are dormant in the fall.

Early foliage spray: Application early in the year, but at or soon after full leaf development.

Fall foliage spray: Application in late summer to early fall, generally used with readily translocated herbicides.

Foliar: Application to the leaves of plants.

Over-the-top (or Overtop): Application over the top of the crop trees.

Pre-emergent: Applied before seedlings or weeds begin to grow (emerge) in the spring. This most often refers to applying an herbicide after the trees are planted but before the weeds begin to grow (pre-emergent herbicide example is Oust XP).

Post-emergent: Used after the crop trees or weeds begin to grow emerged (post-emergent herbicide examples are Velpar and Arsenal).

Pre-plant: Applied before the crop trees are planted.

Post-plant herbaceous weed control: Using herbicides for herbaceous weed control to ensure survival and rapid growth of planted tree seedlings, usually in the spring of the first growing season.

Reforestation: The process of establishing tree seedlings.

Release: The removal of woody or herbaceous weed competition from developing young stands to improve their growth.

Site preparation: Preparing an area for reforestation by mechanical clearing, bedding poorly drained soils, and/or the use of herbicides.

Soil application: Application to the soil rather than to vegetation.

Soil incorporation: Application to the soil followed by tillage to mix the herbicide with the soil (rarely done in forestry).

Soil-spot treatment: Application to a small area of the soil surface.

Stem injection: Application into incisions around a tree stem.

Stump treatment: Application to the top or edges of a tree stump.

Summer foliage spray: Application to mature foliage later in the season.

Timber stand improvement: Selective removal of undesirable trees to improve growing conditions for the desirable residual trees.

Application Methods

Since the primary pesticides used in forested environments are herbicides, the following sections will deal primarily with those materials. However, the application methodology and the calibration of equipment appropriate to apply insecticides and fungicides will involve the same basic techniques but will require different nozzle types, pressures, and rates. If one of these other pesticides will be applied, use the procedures listed below and modify according to directions on the pesticide label.

Foliar and soil-active materials are often broadcast over the entire area to be treated. They can be applied to the foliage or soil by either aerial or ground mechanical equipment. Broadcast applications are common for site preparation. In some areas this method is used for herbaceous weed control and early to mid-rotation woody release.

FOLIAR: Many forestry herbicides (e.g. Roundup Power Max and Forestry Garlon XRT) enter the plant through the green foliage and young stems. Plants that are shielded from foliar sprays by taller or adjacent plants will not be controlled as well as those fully exposed. Adjuvants are added to the spray mixture to aid in the coverage effectiveness or improve safety of these herbicides. However, some formulations already include adjuvants. Always follow label directions. Adjuvants may be particularly useful for late-season use, as foliage can become hardened off and difficult to penetrate.

SOIL-ACTIVE HERBICIDES (e.g. Oust XP and Velpar) may be applied to the soil as liquid or granular formulations. Control will not occur until there is adequate rainfall or sufficient soil moisture. After rainfall dissolves and moves the herbicide into the soil, it is taken up by the roots of established plants. Pre-emergence herbicides (Oust XP) applied to the soil kill vegetation as seeds germinate or new plants grow through the treated ground. Season of the year, soil moisture, temperature, texture, and pH, as well as organic matter and rainfall, greatly affect some soil-active materials.

AERIAL APPLICATION is commonly used to apply pesticides in forestry. This is because tract size is often large, access is often difficult, and the vegetation is usually tall and dense. Large acreages can be treated more economically and in less time by air. Untreated buffers are established around the perimeter of the treatment area. Firebreaks, flagging, or Global Positioning Systems (GPS) are used to mark treatment boundaries and flight lines. Both fixed-wing aircraft and helicopters are used for forestry application insecticides and biological control agents. Forest herbicides are labeled for helicopter application and not by fixed-wing aircraft. Since most states require a separate training and testing for aerial certification, only a brief discussion will follow here.

The use of control droplet aerial (CDA) spray equipment and orienting the nozzles with the air flow causes large droplets. Boom length should be 75 percent of the total wing or blade span. Nozzles located on booms longer than this can cause excessive drift to occur. The larger the droplet, the less chance of drift to non-target sites. Drift-reducing agents and invert emulsions that change the physical composition of spray mixtures can be used to reduce chemical drift. However, when they are large, droplets may reduce the effectiveness of foliar absorbed herbicides. Larger droplet sizes display a tendency to bounce off of leaf surfaces. Large droplets tie-up much more spray volume per drop than do smaller droplets. This may cause inadequate coverage, unless greater volumes per acre are applied.

Spray carrier volume should be adjusted to ensure effective coverage of target vegetation. Water-based formulations require 10-25 gallons per acre (GPA) with the higher carrier volumes necessary when treating multistory canopies and dense vegetation. Oil emulsions use carrier volumes of 10 - 15 GPA, due to costs and deposition efficiency. Aerial applications for mid-story and understory hardwood control requires 15 - 25 GPA to ensure good coverage beneath closed pine canopies.

Solid formulations of soil active materials are also applied aerially. Uniform distribution of solid materials is more difficult than with liquid formulations. Fine particles and dust from the granules can increase the risk of off-site drift. To minimize streaks or skips in the treatment area and off-site movement, apply solid formulations only when wind speeds are less than 5 miles per hour.

MECHANICAL GROUND APPLICATION equipment can be more versatile than aircraft. They can treat small or large areas, do banded or broadcast application, and are not so limited by weather. Crawlers, skidders, 4-wheel drive farm tractors (Figure 60, pg 112), and the sturdier ATV's and UTV's (all-terrain-vehicles and Utility task vehicles; Figure 61, pg 112) can apply herbicides. The selection depends on the job to be done and the site conditions. Ground machine application has definite limits of terrain and stand conditions.

The pesticide application equipment mounted on the machine must be suitable to do the job. Broadcast type sprayers are most commonly used. The application equipment must be able to cover a sizable area efficiently and must be durable. Each component of a properly working sprayer is important for efficient and effective application. The main limit of ground equipment is usually the presence of brush tall enough to mask a major portion of the spray pattern. Spray coverage of plants must be nearly complete, not just on one side, for effective kill.

For boom-type sprayers, flat fan-type nozzles should be used to apply broadcast herbicides. Flat fan nozzles produce an elliptical pattern, where the edges are light and the center is heavy. These should be spaced on the boom for some overlap to produce uniform coverage. When it becomes necessary to apply herbicides in bands, use an even fan or flood nozzle. These nozzles produce a uniform pattern across the area sprayed. The fan nozzles should be operated at pressures of 20 - 40 pounds per square inch (psi). Flood nozzles are designed to operate at lower pressures 5 - 15 psi. The capacity of both nozzle types should be 15 - 20 gallons per acre (GPA) when operated at 2 - 4 miles per hour.

An alternative to broadcast foliar application would be to broadcast a soil-active herbicide. This may be in a granular form that can be applied before full leaf growth masks the distribution. Several liquid formulations also have soil activity.

Banded applications are made with herbicides labeled for herbaceous weed control. Some are labeled for application over-the-top of newly planted trees. These foliar or soil-active materials are applied in 4 to 6-foot wide bands. For resistant perennial species, make a late summer herbicide application at higher rates before seedlings are planted or select a different herbicide.

MANUALLY APPLIED GROUND APPLICATIONS are usually applied using backpack sprayers (Figure 62, pg 112), mist blowers, hand-cranked broadcast spreaders, spotguns, or one of various injection devices. The commonly applied manual treatments used in forestry are listed and explained in the following paragraphs

Directed Foliar

Directed foliar sprays are best used to release 1- and 2-year-old pine stands when brush competition is less than 6 feet tall. Apply the herbicide spray on the target foliage. Direct the spray away from pine foliage and growing tips. The benefits of release can be lost when herbicides are misapplied to needles and shoots, and pines are damaged. Directed foliar sprays are usually applied with a backpack sprayer and a spray wand equipped with a full cone, flat fan, or adjustable cone spray tip.

Full Basal Sprays

Full basal sprays require that the lower 12 - 20 inches of target hardwood stems be completely wet on all sides with the spray mixture. Full basal sprays are effective on target stems. A backpack sprayer is used with a wand or spray gun fitted with a narrow-angle flat fan, cone, or adjustable tip.

Streamline Basal Sprays

Streamline basal sprays can control many woody plants including hardwoods up to 2 inches in diameter at breast height (dbh; 4.5 feet above groundline). Trees of susceptible species up to 6 inches in diameter can be controlled. However, treatment of small hardwoods less than 2 inches dbh results in the most control.

For stems less than 2 inches dbh, apply the stream of spray up and down single stems for about 6 - 8 inches or spray across multiple stems creating a 2-3-inch-wide band. Direct the spray stream to smooth juvenile bark at a point about 6 - 24 inches from the ground. Stems that are beyond the juvenile stage, thick barked, or near 3 inches in diameter require treatment on both sides, unless they are susceptible species. Back-and-forth bands can also be sprayed on larger stems.

Apply in late fall to winter when leaves do not hinder spraying the stem. The best application time will depend on the herbicide, species, and location. Avoid applications in young pine plantations on hot days (temperature greater than 86 degrees F) if an ester herbicide formulation is used because pine injury may occur from vapor drift.

Tree Injection

This method can be used alone or in combination with other individual stem treatments for site preparation, pine and hardwood release, timber stand improvement, stand conversion, and creating cavity trees for nesting. This physically demanding method requires workers who can repeatedly and precisely chop into tree trunks deep enough to properly deliver herbicide for uptake in the sap flow. Frequent sharpening and maintenance of injection tools is needed for best results.

Commonly used tree injection methods are: the hack-and-squirt, hypo-hatchets, and tubular tree injectors. Waist-high injections by the hypo-hatchet and hack-and-squirt methods are just as effective and as fast to perform as basal injections. With larger stems, apply more herbicide by basal injections because of the larger groundline diameter compared to diameter at breast height.

The best time of year to perform the hack-and-squirt, hypo-hatchet, and tubular tree injector treatments are late fall into dormant season prior to new growth in the spring. Another option is to wait until after full leaf-out during early to mid-summer to do these same treatments.

Hack-and-squirt (Figure 63, pg 113) is an effective and economical means of selectively controlling undesirable hardwood stems. A lightweight hatchet is used to cut into the tree stem through the cambium, and an herbicide is sprayed on the cut from a trigger squeeze bottle.

The hypo-hatchet is a hatchet with an internal herbicide delivery system connected by a hose to an external herbicide container. When the hatchet strikes a tree, the blade must penetrate into the sapwood. The impact of the striking action drives a piston forward that delivers 1 ml of herbicide into the cut. The rate cannot be adjusted. Daily cleaning and lubrication of the impact piston is required maintenance, along with periodic replacement of rubber O-rings and seals. Always wear safety glasses when using the hypo-hatchet because of frequent herbicide splashes.

CAUTION: All hoses and fittings should be checked daily for leaks and appropriate repairs made to prevent applicator exposure.

Tubular tree injectors have a long metal tube fitted with a chisel-type blade that is used to cut through the tree bark into the sapwood near the base of the tree. The unit is equipped with a lever, handle, or wire, which is pulled to deliver the herbicide (usually 1 ml) from the cylinder into the cut. The delivery rate can be adjusted for accurate calibration.

Treating Stumps

Treating stumps with herbicide can prevent resprouting of many species. This can be an effective, low cost treatment following harvest for site preparation and after partial cuts for timber stand improvement. Hand clearing treatments using saws or axes for pine release can be enhanced by treating the stumps with herbicide to prevent sprouting and regrowth. A backpack sprayer can be used that has a wand or spray gun equipped with a straight stream, fan, or hollow-cone nozzle. Alternatively, a sawyer can carry herbicide in a utility spray bottle for treating stumps after cutting; or use a wick applicator for small diameter stumps.

Treat freshly cut stumps as soon as possible after cutting. For stumps over 3 inches in diameter, completely wet the outer edge, or cambial area, with the herbicide (Figure 64, pg 114). Smaller stumps are usually completely wetted (Figure 65, pg 114). To be successful, treat all small stumps. The sawyer or companion applicator should treat soon after felling so no stumps are skipped. Treat older, cut stumps with the streamline mixture. The mixture is applied to the outer 1 - 2 inch edge of the stump until runoff and to the base of any sprouts. Stump treatments within four hours of cutting have been shown effective, the sooner the better.

Spots of Soil-Active Herbicide

Spots of soil-active herbicide are applied to the soil surface in grid patterns or around target stems for site preparation and pine release. This method is effective in controlling stems up to 10 inches dbh. Apply exact amounts of herbicide, specified in milliliters (ml), to the soil surface at prescribed spacings. The effectiveness of the treatment depends on the applicator's accuracy and consistency in amount applied and spacing.

Spots are applied to the soil by using a spot-gun (Figure 66, pg 114) or a spray-gun equipped with a straight-stream spray tip. The spot gun delivers a set amount while the spray-gun method requires training to judge the amount applied. A spot gun is an adjustable graduated cylinder or syringe operated by squeezing the handle. A forceful squeeze can project spots up to 15 feet. A spray gun uses pressure from the backpack sprayer to project spots to over 20 feet, requiring less exertion. Both can be connected to a backpack sprayer, and the spot gun can also be connected to a side-pack container.

Granules and Pellets

Granules and pellets can be applied by hand-cranked spreaders, air-blown backpack spreaders, and hand broadcast. Hand-cranked broadcast spreaders can distribute granular or pelletized herbicides on small tracts and areas with steep slopes or rough terrain. They can be used where machine spreaders are not suitable. Advantages of hand operated spreaders are that they are small, simple, inexpensive, and generally reliable hand tools. Unfortunately, uniform application is often difficult to obtain, and treatment is slow and laborious.

OTHER CONSIDERATIONS

The forest manager must be aware of all of the environmental and personal safety concerns associated with using pesticides. Federal and state efforts to protect individuals, wildlife, and the environment from harm and contamination are becoming important issues to determine which pesticides will be registered and for what use.

Both current and developing limits and restrictions with pesticide use should be known by the forest manager who enforces all safety precautions and environmental safeguards. Pesticides that are incorrectly released into the environment (whether during application, mixing, loading, equipment cleaning, storage, transportation, or disposal of pesticides) pose a threat to individuals, wildlife, endangered species, and both surface and groundwater. Forestry pesticides are often applied to large areas which frequently consist of diverse habitats encompassing streams, rivers, estuaries, swamps, or open water. These diverse habitats may be home to humans, domesticated animals, and terrestrial, aquatic and/or marine organisms. Consequently, special limits and restrictions often apply to pesticide use in forests. Always read and follow label directions.

Report fish or wildlife kills in pesticide treated or adjacent areas to the appropriate natural resource agency. The agency may want to investigate the reason for such a kill to help prevent future occurrences. Many conditions other than pesticides can kill fish or wildlife.

Beneficial Forest Insects

There are many types of beneficial forest insects, such as predators, detritivores (break down dead organic matter), and parasites. Some of these insects feed on forest debris and aid in its deterioration. Other beneficial insects feed on organic matter in the duff and soil, and they contribute to improvements in soil fertility.

Parasites and predators may reduce populations of problematic insect pests. Many insects are important food sources for birds and other small animals. Pollinators, like native bees and some flies, beetles, and wasps, improve sustainability of many commercial crops and forest plants. Forest managers and pesticide applicators must always be mindful of beneficial insects and other wildlife in the forest environment. Pesticide labels give useful information about toxicity to non-target life forms. Learn as much as possible about the health and environmental hazards of the pesticides that may be used. Read the entire pesticide label before using a product. Select the pesticide and application method that will have the least adverse impact and still appropriately manage the pest population.

Prescribed Burning

Prescribed burning is often employed to help control undesirable forest species. It also can help reduce brown spot needle blight on longleaf pine seedlings and Annosum root disease in southern pines, as well as other undesirable forest conditions. Prescribed burning can be an important part of most chemical site preparations treatments. Not only does burning add to the herbicide kill, it helps clear the site to facilitate reforestation work. When properly timed and executed, prescribed fire has little adverse effect on the environment. However prescribed burning and other non-chemical pest control measures can present risks and have undesirable effects. Prepare a written prescribed burning plan before each burn to identify measurable objectives for burning and specific conditions under which the burn will be conducted. Be sure to make a smoke management screening evaluation and conduct a follow up evaluation of the effectiveness of your prescribed burn. In most states you must contact the local Forestry Commission/Department office for a burning permit before you start the burn.

Endangered Species Act

The Endangered Species Act provides:

- Legal protection for endangered and threatened species.
- Requires all federal agencies (for example, U.S. Forest Service, U.S. Fish and Wildlife Service, Bureau of Land Management) to ensure their actions will not jeopardize the existence of any endangered species.
- Many endangered species inhabit forests in the United States. Some pesticides presently labeled for use in forests are considered to have an adverse effect on one or more endangered species.
- Since 1988, every affected pesticide has a warning on the label:
    - Label prohibits pesticide use in occupied habitat of endangered species.
    - Ranges are identified to county level.
    - Pesticides are to be used in identified counties permitted only if not within the range of endangered species.

An information bulletin should be available in those counties of a state listed on the label. The information bulletin will have a county map giving the boundaries of those areas of the county where the use of the pesticide will have some restrictions, the endangered species affected, and a description of its habitat.

Information bulletins should be available through local county Extension and state forestry offices. Each state will have an “enforcement plan” to implement the Endangered Species Act.

APPENDIX A

Sprayer Calibration

Calibration determines the amount of material applied per acre within the area to be covered. By knowing the amount of material applied per acre, the rate of pesticide can be dispersed according to label directions. Calibrate with clean water when applying toxic pesticides that will be mixed with large volumes of water. When applying liquid materials, check uniformity of nozzle output across the boom or band. Collect spray from each nozzle for a known time period. Each nozzle should be within five percent of the average output. Replace worn or malfunctioning nozzles as necessary. When applying materials that are appreciably different from water in weight or flow characteristics (such as fertilizer solutions, etc.), calibrate with the material to be applied. Exercise extreme care and use protective equipment when active ingredients are involved.

BOOM SPRAYER CALIBRATION: The procedure below (Step 1 through Step 7) is based on spraying 1/128 of an acre and collecting the spray that would be released during the time it takes to spray the area. There are 128 ounces of liquid in 1 gallon, so in this equation, ounces of liquid caught are equal to the application rate in gallons per acre.

Step 1. Determine appropriate calibration distance from spacing of outlets or nozzles. Find this spacing in left column of the table and read the corresponding calibration distance. (Table 4, pg 80) Example: for a 19-inch spacing, the distance would be 214.9 feet.

Step 2. Measure and mark calibration distance on typical terrain to be sprayed.

Step 3. Traveling at the desired operating speed, determine the number of seconds it takes to travel calibration distance. Be sure machinery is traveling at full operating speed for the full length of the calibration distance. Mark or note engine revolutions per minute (RPM) and gear. **Machine must be operated at same speed for calibration and pesticide application.**

Step 4. With the sprayer sitting still and operating at same throttle setting or *engine RPM* as used in Step 3, adjust pressure to the desired setting. **Machine must be operated at same pressure used during calibration.**

Step 5. Collect spray from one nozzle or outlet for the number of seconds required to travel the calibration distance.

Step 6. Measure the amount of liquid collected in fluid ounces. The number of ounces collected is the gallons per acre rate. For example, if you collect 18 ounces, the sprayer will apply 18 gallons per acre. Adjust the applicator speed, pressure, nozzle size, etc. to obtain recommended rate. If speed is adjusted, start at Step 3 and recalibrate. If pressure or nozzles are changed, start at Step 4 and recalibrate.

Step 7. To determine amount of pesticide to put into a sprayer, divide the total number of gallons of mixture to be made (tank capacity for a full tank) by the gallons per acre rate from Step 6 and use recommended amount of pesticide for this number of acres.

Table 4. Boom sprayer calibration distances with corresponding widths

Outlet Spacing (inches)**	Calibration Distance (Feet)
48	85.1
46	88.8
44	92.8
42	97.2
40	102.1
38	107.5
36	113.4
32	127.6
30	136.1
24	170.2
20	204.2
19	214. 9
18	226.9
14	291.7
12	340.3
10	408.4
8	510.5

** To determine distance for spacing, divide the spacing expressed in feet into 340.3.
Example: For a 13" band, the calibration distance would be 340 divided by 13/12=314. l.

BOOMLESS BROADCAST AND BAND SPRAYERS CALIBRATION

Most broadcast applications are made with a boom arrangement where the nozzle tips are spaced evenly along the boom. However, in some situations this may be impossible or undesirable, so a cluster nozzle, or a single nozzle with a wide spray pattern, may be used. The following instructions (Step 1 through Step 6) outline a simple method to calibrate a boomless broadcast or band sprayer.

Step 1. Determine spray width. This is usually given in the manufacturers' literature for a specific nozzle. If you are unable to find this information, use 80-85 percent of the wetted spray width. Another recommended option is to determine spray width of the boomless sprayer for each use by spraying (using water) the boomless sprayer at the proper PSI (typically 20-40 psi). Noting the psi in the area to be sprayed, measure the wetting length from the boomless nozzles to the end of the wetting area. When spraying in low growing grasses (pastures or hay-fields), the spray width will be greater than spraying in a cutover site pre-plant or in young planted pines with mixed herbaceous weeds and some woody vegetation of various heights. This vegetation can potentially reduce spray width by 10-25%. **Note also the boomless sprayer nozzles height above the ground. The boomless sprayer nozzles height needs to be the same when calibrating and spraying an area.**

Step 2. Using the spray width in Step 1, determine the calibration distance from Table 5 (pg 83) below.

Step 3. Measure and mark calibration distance on **typical** terrain to be sprayed.

Step 4. With all attachments in operation and traveling at the desired operating speed, determine the number of seconds it takes to travel the calibration distance. Be sure machinery is traveling at full operating speed for the full length of the calibration distance. Mark or note engine RPM and gear. **Machine must be operated at same speed during use as was used during calibration**.

Step 5. With the sprayer sitting still and operating at same throttle setting or *engine RPM* as used in Step 4, adjust pressure to the desired setting. **Machine must be operated at same pressure used for calibration during the actual application.**

Step 6. Collect spray from all nozzles or outlets for the number of seconds required to travel the calibration distance.

Step 7. Measure the amount of liquid collected in fluid ounces.

Step 8. Divide the total number of fluid ounces by 10 to obtain gallons per acre applied. For example, if you collect 180 ounces, the sprayer will apply 18 gallons per acre. Adjust the applicator speed, pressure, nozzle size, etc. to obtain recommended rate. If speed is adjusted, start at Step 4 and recalibrate. If pressure or nozzles are changed, start at Step 5 and recalibrate.

Step 9. To determine amount of pesticide to put into a sprayer or applicator tank, divide the total number of gallons of mixture to be made (tank capacity for a full tank) by the gallons per acre rate from Step 8 and use recommended amount of pesticide for this number of acres.

Table 5. Boom broadcast or band sprayer calibration distances with corresponding widths

Swath Width (feet)**	Calibration Distance (feet)
40	85.1
38	89.5
36	94.5
32	106.3
30	113.4
28	121.5
26	130.9
24	141.8
20	170.2
18	189.0
16	212.7
12	283.6
10	340.3
8	425.0

** To determine distance for swath width not listed, divide the swath width expressed in feet into 340.3 and multiply by 10.

Example: For a 13 feet swath, the calibration distance would be 340.3 divided by 13 multiplied by 10=261.8 feet.

HAND SPRAYER CALIBRATION

Hand sprayers should be calibrated before applying any materials. The method described is easy, quick, and accurate if measurements are made carefully. The procedure is for banded applications with backpack sprayers but will also work with most hand sprayers.

Step 1. On an area that best represents the average topography for the area to be sprayed, measure and mark off the calibration distance that coincides with your band width indicated in Table 6, pg 86.

Step 2. Fill the sprayer with water only, and record the number of seconds required to walk the calibration distance at a comfortable, steady speed while spraying and pumping to maintain a uniform pressure.

Step 3. While pumping to maintain the selected application pressure, collect spray from all nozzles used on one band width for the number of seconds required to travel the calibration distance.

Step 4. Measure the amount of liquid collected. **The number of ounces collected is equal to the gallons of water applied per acre for that bandwidth, speed, and pressure**. For example, if you collect 20 ounces, the sprayer will apply 20 gallons per acre.

Step 5. To determine the amount of chemical to add to the spray tank, divide the capacity of the tank by the number of gallons of water per acre (GPA) to determine the fraction of an acre that can be covered with a tankful of spray.

Step 6. Multiply the application rate of the product per acre times the fraction of the acre covered per tank and add that amount of chemical to the sprayer tank.

Uniform Application Check - Hand sprayers require skilled operators to achieve a uniform application. A simple and quick test of uniformity is to spray an area on a paved surface with water in your normal spraying manner on a warm day. In a few minutes, the drying pattern will indicate your distribution. Fast-drying areas indicate low application rates while slow-drying areas received high amounts of spray. Uniform drying without streaks indicates uniform application. Practice until uniform distribution is obtained.

Table 6. Hand sprayer calibration distances with corresponding band widths.

Band Width (inches)	Calibration Distance (feet)
48	85.1
46	88.8
44	92.8
42	97.2
40	102.1
38	107.5
36	113.4
32	127.6
30	136.1
24	170.2
20	204.2
19	214.9
18	226.9
14	291.7
12	340.3
10	408.4
8	510.5

** To determine distance for spacing, divide the spacing ex▪ pressed in feet into 340.3.
Example: For a 13" band the calibration distance would be 340 divided by 13/12=314.1.

GRANULAR HERBICIDE CALIBRATION

The following procedure will give the pounds (total weight) of material applied per acre broadcast. This calibration procedure is based on 1/16th of an acre, which is equal to 16 ounces in a pound of material. A weight scale incremented in ounces is required for this procedure. Check uniformity of outlets across the swath. Collect from each outlet for a known time period. Each outlet should be within 5 percent of the average output. Exercise extreme care and use protective equipment when an active ingredient is involved.

Step 1. Determine appropriate calibration distance from Table 7, pg 88.

Step 2. Measure and mark calibration distance in **typical** terrain to be applied.

Step 3. With all attachments in operation and traveling at the desired operating speed, determine the number of seconds it takes to travel the calibration distance. Be sure machinery is traveling at full operating speed for the full length of the calibration distance. Mark or note engine RPM**; during application, machine must be operated at same speed used for calibration**.

Step 4. With applicator sitting still and operating at same speed as used in Step 3, adjust gate openings to desired setting.

Step 5. Collect from all outlets for the number of seconds indicated in Step 3.

Step 6. Weigh the amount of material collected in ounces. The number of ounces collected is the pounds per acre rate. For example, if you collect 18 ounces, the applicator will apply 18 pounds per acre. Adjust applicator speed, gate opening, etc. to obtain recommended rate.

Table 7. Granular herbicide calibration distances with corresponding widths

Swath Width (feet)**	Calibration Distance (feet)
80	34.0
70	38.9
60	45.3
50	54.4
40	68.1
30	90.7
25	108.9
20	136.1
15	181.5
10	272.2
8	340.3
6	453.7
4	680.6
2	1361.2

**To determine distance for a swath width not listed, divide the swath width expressed in feet into 2,722.5.
Example: For 13 feet swath, the calibration distance would be 2,722.5 divided by 13=209.4 feet.

SPOT HAND OR BACKPACK SPRAYER APPLICATION METHOD

Spot applications are one of the most common uses of a backpack sprayer. Spot treatments of undesirable vegetation that is not uniformly scattered around a site is frequently needed. This type of treatment is often used to treat invasive plants, shrubs, and sapling-size trees. Calibration of a backpack sprayer for these types of situations is important for correct herbicide application rates.

Spot application should be considered in “treated” acres. This refers to the sum of the total area of plants to be treated across a site. Sites are often variable in the density and size of target vegetation. Calibration requires finding vegetation patches similar in density and size to target vegetation you will encounter during actual applications. In many situations, it may be easiest to calibrate your backpack sprayer on the vegetation you plan to treat (without herbicides added). The steps outlined below use the 1/128th of an acre calibration method. Remember, it is important to use the same nozzle during calibration as you would during the actual application.

Step 1. Establish a calibration area equal to 340 ft^2 that has similar vegetation structure to the target plants (e.g. if you plan to spray 8-12 feet tall Chinese privet shrubs that are growing directly beside each other along a field edge, think of a “wall” of privet, find a field edge, forest opening edge, or fencerow with similar vegetation structure and size to calibrate your sprayer). In many instances, you can calibrate your sprayer on the vegetation you plan to target. Measure the calibration vegetation to a height that can comfortably be sprayed and measure the distance needed to spray 340 ft^2. Example: if you can comfortably spray up to 9 feet (vertical) from the ground: 340 ÷ 9 = 37.8 feet horizontal distance.

Mark this distance and spray the height along your calibration area using a reel tape and flagging to ensure more precise calibration.

Step 2. Prior to spraying, mark the water level in your tank using a dry erase marker or chalk. Fill the tank to a known volume (e.g. 3-gallon mark) so that you know how many gallons or ounces were present prior to spraying. Spray the calibration area in the same manner as you would the target spray area by using the same sprayer pressure, spray patterns, and the same amount of vegetation wetting. Using a colored dye in the tank can help visualize how wet the vegetation is after spraying. Practicing this step multiple times can result in more consistent results, but be sure to mark the water level in the tank prior to starting another calibration run.

Step 3. The "subtraction" method can then be used to calculate ounces applied over the calibration area. Use a measuring cup to carefully refill the sprayer back to the predetermined starting mark. For example, suppose it required 30 ounces to refill the spray tank back to the 3-gallon mark. This means you were spraying 30 gallons per acre if sprayer pressure, spray patterns, and vegetation wetting are consistent.

Step 4. The next step is to determine the amount of herbicide needed based on label or recommended application rates since you know the per acre spray volume. If the target species requires a 20% solution of an herbicide, this percentage needs to be converted over to ounces per gallon. If your sprayer can comfortably hold 3.5

gallons or 448 ounces, 448 x 0.2 = 89.6 ounces. This rate would require 89.6 ounces of herbicide and 358.4 ounces of water. Per gallon, this would equate to 25.6 ounces of active ingredient and 102.4 ounces of water for one gallon of total solution (25.6 + 102.4 = 128 ounces in a gallon). For another example, a recommended application rate calls for 1.5 quarts per acre. 1.5 quarts = 48 ounces. If you are spraying 30 gallons per acre, 48 ounces ÷ 30 = 1.6 ounces per gallon. Therefore, to mix 3.5 gallons in a backpack sprayer, 1.6 x 3.5 = 5.6 ounces per spray tank.

Practice using this method to ensure more precise herbicide applications for spot spray treatments. If the vegetation you are targeting occurs in multiple size classes, it may be beneficial to calibrate using the steps outlined in this section on the different sizes of vegetation you expect to encounter when spot spraying an area using a backpack sprayer or hand sprayer.

TABLE AND FIGURES INDEX

Figure 1. Loblolly-shortleaf pine forest example

Image credit: David Clabo, University of Georgia

Figure 2. Oak-hickory forest example

Image credit: David Clabo, University of Georgia

Figure 3. Longleaf-slash pine forest example

Image credit: Cassandra Waldrop, University of Georgia

Figure 4. Oak-gum-cypress forest example

Image credit: David Clabo, University of Georgia

Figure 5. Oak-pine forest example

Image credit: David Clabo, University of Georgia

Figure 6. Elm-ash-cottonwood forest example

Image credit: David Clabo, University of Georgia

Figure 7. Southern pine beetle adult

Image credit: Jiri Hulcr,
University of Florida

Figure 8. Southern pine beetle S-shaped galleries

Image credit: Elizabeth McCarty,
University of Georgia

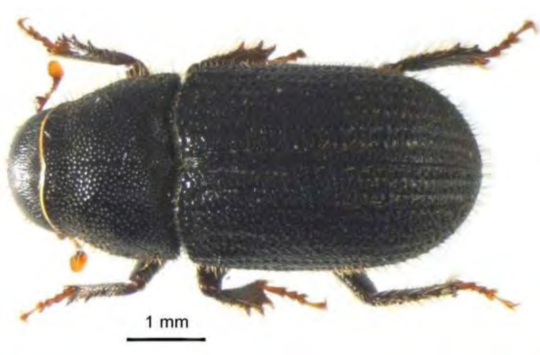

Figure 9. Black turpentine beetle adult

Image credit: Jiri Hulcr,
University of Florida

Figure 10. Black turpentine beetle gallery

Image credit: Elizabeth McCarty,
University of Georgia

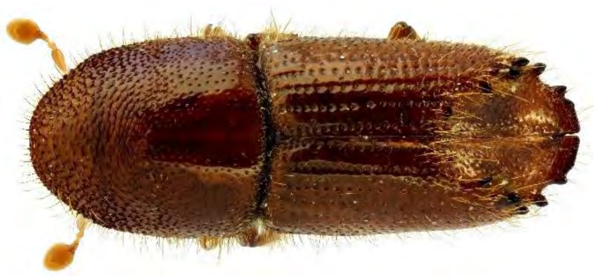

Figure 11. Engraver beetle adult

Image credit: Jiri Hulcr,

University of Florida

Figure 12. Engraver beetle gallery

Image credit: Elizabeth McCarty, University of Georgia

Figure 13. Nantucket pine tip moth adult

Image credit: Elizabeth McCarty, University of Georgia

Figure 14. Nantucket pine tip moth damage

Image credit: Elizabeth McCarty, University of Georgia

Figure 15. White pine weevil damage

Image credit: Steven Katovich,
Bugwood.org

Figure 16. Deodar weevil tunneling and chip cocoon.

Image credit: Elizabeth McCarty,
University of Georgia

Figure 17. Deodar weevil adult

Image credit: Elizabeth McCarty,
University of Georgia

Figure 18 Emerald ash borer adult

Image credit: Debbie Miller,

USDA Forest Service, Bugwood.org

Figure 19. Emerald ash borer tunneling

Image credit: Elizabeth McCarty, University of Georgia

Figure 20 . Asian longhorned beetle

Image credit: Michael Bohne, USDA Forest Service, Bugwood.org

Figure 21 Asian longhorned beetle damage

Image credit: Pennsylvania Department of Conservation and Natural Resources, Bugwood.org

Figure 22. Pales weevil feeding damage.

Image credit: Lacy L. Hyche, Auburn University, Bugwood.org

Figure 23. *L. dispar* adult female (white) and male (brown).

Image credit: USDA APHIS PPQ, Bugwood.org

Figure 24. *L. dispar* caterpillar

Image credit: Jon Yuschock, Bugwood.org

Figure 25. Redheaded pine sawfly

Image credit: Elizabeth McCarty, University of Georgia

Figure 26 Blackheaded pine sawfly

Image credit: Elizabeth McCarty, University of Georgia

Figure 27. Pine webworm nest

Image credit: Elizabeth McCarty, University of Georgia

Figure 28. Pine webworm caterpillar

Image credit: Elizabeth McCarty, University of Georgia

Figure 29 Fall webworm nest

Image credit: Elizabeth McCarty, University of Georgia

Figure 30. Black-headed (top) and red headed (bottom) fall webworm

Image credit: Elizabeth McCarty, University of Georgia

Figure 31. Pink-striped oakworm

Image credit: Elizabeth McCarty, University of Georgia

Figure 32. Sycamore lace bug

Image credit: Elizabeth McCarty, University of Georgia

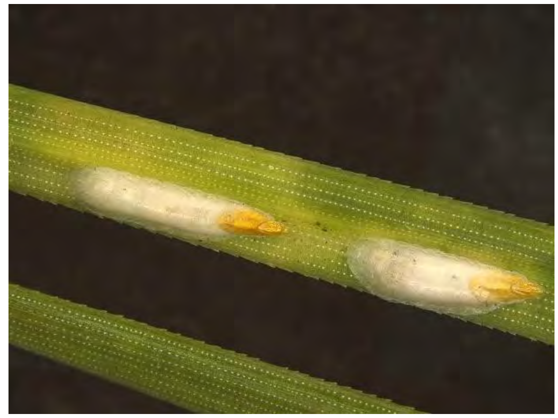

Figure 33. Pine needle scale

Image credit: Elizabeth McCarty, University of Georgia

Figure 34. Aphid feeding on pine.

Image credit: Elizabeth McCarty, University of Georgia

Figure 35. Hemlock woolly adelgid

Image credit: Elizabeth McCarty, University of Georgia

Figure 36. Windthrow caused by Heterobasidion root disease

Image credit: Michelle Cram, USDA Forest Service

Figure 37. *Heterobasidion irregulare* conks at base of tree

Image credit: USDA Forest Service

Figure 38. White-stringy root rot symptom of Heterobasidion root disease

Image credit: Michelle Cram, USDA Forest Service

Figure 39. Littleleaf disease of shortleaf pine in 1958, Sumter National Forest

Image credit: USDA Forest Service

Figure 40. Shortleaf pine crown symptoms of littleleaf disease

Image credit: Stephen Fraedrich, USDA Forest Service

Figure 41. Windthrow of eastern white pine caused by brown cubical rot

Image credit: Michelle Cram, USDA Forest Service

Figure 42. Fusiform rust canker on the main stem

Image credit: Michelle Cram, USDA Forest Service

Figure 43. Fusiform rust canker on a seedling

Image credit: Michelle Cram, USDA Forest Service

Figure 44. Pitch canker on a Virginia pine stem

Image credit: Michelle Cram, USDA Forest Service

Figure 45. Eastern white pine bast scale (cyst stage)

Image credit: Michelle Cram,

USDA Forest Service

Figure 46. Caliciopsis canker with fruiting bodies surrounding a bast scale (cyst stage) covered in resin

Image credit: Michelle Cram,

USDA Forest Service

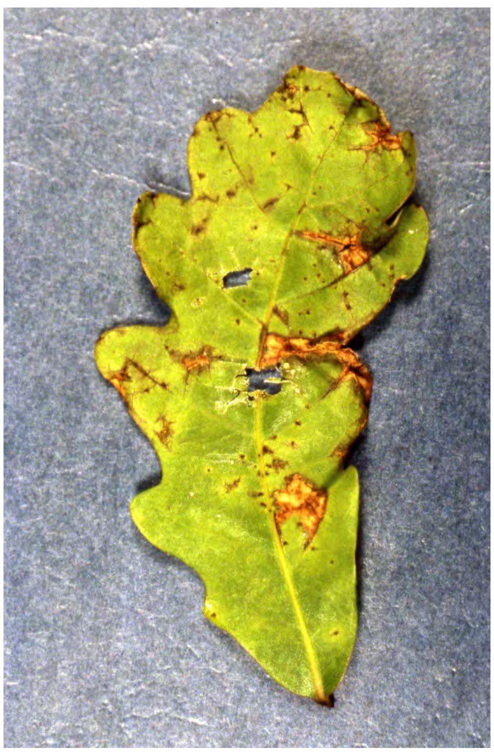

Figure 47. Oak leaf anthracnose

Image credit: Michelle Cram,
USDA Forest Service

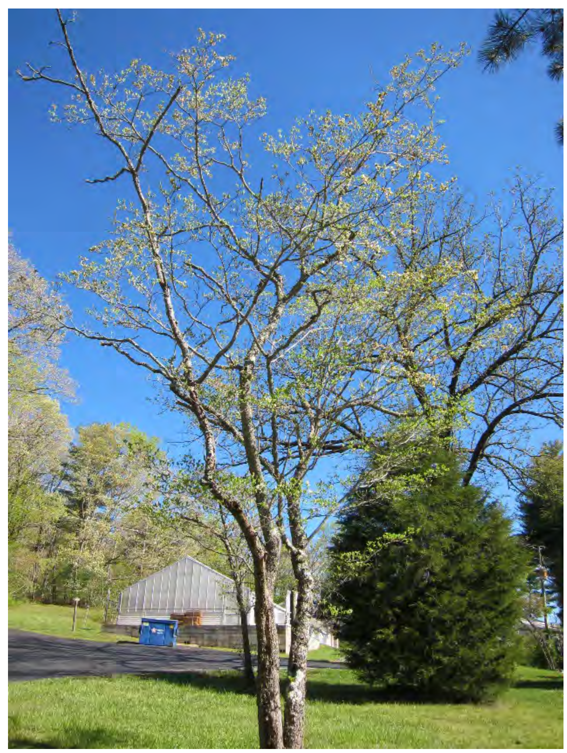

Figure 48. Flowering dogwood affected by dogwood anthracnose.

Image credit: Michelle Cram,
USDA Forest Service

Figure 49. Loblolly pine stand with severe needlecast disease

Image credit: Dana Stone, Alabama Forestry Commission

Figure 50. Brown spot needle blight on longleaf needles

Image credit: Edward Barnard, Florida Division of Forestry

Figure 51. Redbay ambrosia beetle attack and sapwood discoloration from the laurel wilt pathogen

Image credit: Stephen Fraedrich, US Forest Service

Figure 52. Redbay killed by laurel wilt

Image credit: Stephen Fraedrich, USDA Forest Service

Figure 53. Foliage symptoms of oak wilt

Image credit: Joseph O'Brien,

USDA Forest Service

Figure 54. Sporulating mat on red oak killed by oak wilt

Image credit: John N. Gibbs,

Forestry Commission Research, England

Figure 55. Deer tree rubbing

Image credit: Michael Kohl, University of Georgia

Figure 56. Feral hog tree rubbing

Image credit: USDA Wildlife Service

Figure 57. Beaver-felled tree

Image credit: USDA Wildlife Services

Figure 58. Yellow-bellied sapsucker damage

Image credit: Michel Kohl, University of Georgia

Figure 59. Example of kudzu vines growing over vegetation and trees

Image credit: Bugwood.org

Figure 60. Tractor mounted boom sprayer

Image credit: David Dickens, University of Georgia

Figure 61. ATV mounted boomless sprayer

Image credit: Mike Hayes,

University of Georgia

Figure 62. Backpack sprayers being prepared for an herbicide study

Image credit: David Dickens, University of Georgia

Figure 63. The method of applying an herbicide in the hack-and-squirt system

Image credit Dave Moorhead, University of Georgia

Figure 64. Cut stump herbicide treatment covering the outer (living tissue area) part of the stump and 1-2 inches below the stump. Treating the stump as soon as possible after cut provides best results.

Image credit: Dave Moorhead, University of Georgia

Figure 65. Cut stump herbicide treatment covering the entire stump and 1-2 inches of bark below the stump.

Image credit: Dave Moorhead, University of Georgia

Figure 66. A spot gun that can attached to a backpack sprayer to deliver small herbicide (1-4 ml undiluted for some herbicides) doses in a grid pattern or at the base of woody competition

Image credit: Dave Moorhead, University of Georgia

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