# FOREST PEST CONTROL

This manual was developed in cooperation with the Georgia Department of Agriculture.
COOPERATIVE EXTENSION SERVICE THE UNIVERSITY OF GEORGIA
COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES
WARNELL SCHOOL OF FOREST RESOURCES

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This training manual is presented in a printed version and as an enhanced, interactive electronic version on a CD-ROM inserted in a sleeve in the back inside cover. 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 your state certification examination, 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 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 1996 revision of the EPA manual, **Applying Pesticides Correctly: A Guide for Commercial Applicators.**

The electronic version of this manual has similar content to the printed version, allows for increased use of color visuals, and allows for user interaction. The manual is available on CD-ROM and on our web site at **http://www.bugwood.org/pestcontrol/.** Both versions contain high-resolution color versions of the images included in the printed manual, as well as links to other online resources and additional images.

The catagorization of organisms used in this work is based upon a coding scheme developed for use in the USDA Forest Service Pest Trend Impact Plot System (PTIPS) database application (now part of the FSVEG system). PTIPS is a multi-purpose database application designed to aid in storage and retrieval of insect, disease and vegetation information collected from plots across Forest Service regions. The comprehensive PTIPS project coding scheme provides for a breakout of organisms that includes insects, diseases, and hosts. We realize that there are many other possibilities for organismic groupings, but we chose to use the PTIPS system to allow for easier alignment with other projects. (Adams et al. 1994).

This revised printed and CD-ROM Manual was developed by The Bugwood Work Group, based in Tifton, Georgia, USA. The Work Group is a cooperative effort between personnel in The Department of Entomology in The College of Agricultural and Environmental Sciences and The Warnell School of Forest Resources at The University of Georgia.

Drs. G. K. Douce and D. J. Moorhead coordinate The Work Group. The computer aspects of this project were designed and implemented by these Work Group members

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Visit our Worldwide Web site ***http://www.bugwood.org*** for updates and additional information on this project and others produced by The University of Georgia, College of Agricultural and Environmental Sciences and The Warnell School of Forest Resources, Bugwood Work Group.

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 agriculture from the University of Georgia, visit The College of Agricultural and Environmental Sciences web site at: ***http://www.uga.edu/~caes/***

If you have problems or need additional information about the operation of the CD-ROM or Web version contact us at (229) 386-3298 or via E-mail at: ***bugwood@arches.uga.edu***

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Computer systems' requirements for successful use of the electronic manual are:

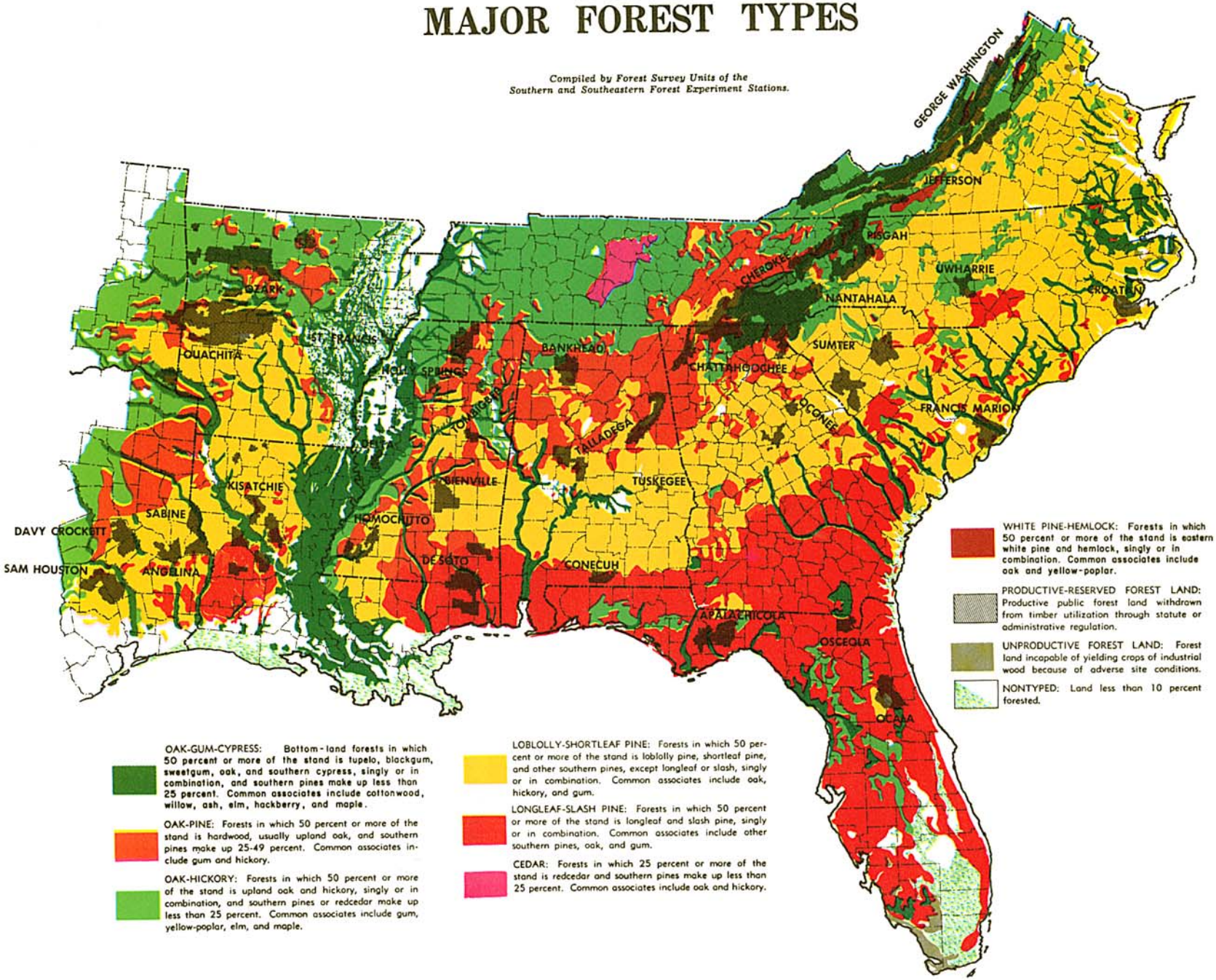
Recommended--

Pentium II 400mhz with 64 Megabytes of RAM and 8x or higher CD player, monitor and video card capable of thousands of colors, and mouse

Microsoft Internet Explorer 5.0 or greater; or Netscape Navigator 4.5 or greater is requred to run CD-ROM version or view Web version

# MAJOR FOREST TYPES

*Compiled by Forest Survey Units of the Southern and Southeastern Forest Experiment Stations.*




OAK-GUM-CYPRESS: Bottom-land forests in which 50 percent or more of the stand is tupelo, blackgum, sweetgum, oak, and southern cypress, singly or in combination, and southern pines make up less than 25 percent. Common associates include cottonwood, willow, ash, elm, hackberry, and maple.

OAK-PINE: Forests in which 50 percent or more of the stand is hardwood, usually upland oak, and southern pines make up 25-49 percent. Common associates include gum and hickory.

OAK-HICKORY: Forests in which 50 percent or more of the stand is upland oak and hickory, singly or in combination, and southern pines or redcedar make up less than 25 percent. Common associates include gum, yellow-poplar, elm, and maple.

LOBLOLLY-SHORTLEAF PINE: Forests in which 50 percent or more of the stand is loblolly pine, shortleaf pine, and other southern pines, except longleaf or slash, singly or in combination. Common associates include oak, hickory, and gum.

LONGLEAF-SLASH PINE: Forests in which 50 percent or more of the stand is longleaf and slash pine, singly or in combination. Common associates include other southern pines, oak, and gum.

CEDAR: Forests in which 25 percent or more of the stand is redcedar and southern pines make up less than 25 percent. Common associates include oak and hickory.

WHITE PINE-HEMLOCK: Forests in which 50 percent or more of the stand is eastern white pine and hemlock, singly or in combination. Common associates include oak and yellow-poplar.

PRODUCTIVE-RESERVED FOREST LAND: Productive public forest land withdrawn from timber utilization through statute or administrative regulation.

UNPRODUCTIVE FOREST LAND: Forest land incapable of yielding crops of industrial wood because of adverse site conditions.

NONTYPED: Land less than 10 percent forested.

# Forest Pest Control

## FOREST RESOURCES

The thirteen southern states, Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia, hold 40 percent of the nation's timberland. This 212 million acre timber resource represents two of every five acres in the region. Alabama, Georgia, North Carolina and Virginia each have approximately 65 percent of their total state land area forested. The majority of southern forests are privately owned with 62 percent held by nonindustrial private landowners and farmers. Forest industry owns 20 percent, with non-forest industry holding 8 percent across the region. Only 10 percent of the South's forest land is in public ownership.

This southern forest resource has become the nation's wood basket for forest growth and production. Twenty three percent of the nation's growth of softwood timber and 44 percent of the hardwood timber is in this region. Southern timber harvests produce 43 percent of the nation's softwood logs, 53 percent of the hardwood sawlogs, and over 50 percent of the plywood logs. Two-thirds of the nation's pulpwood is produced in the South. The 105 pulp mills located in the thirteen southern states require over 60 million cords of pulpwood per year to run full capacity.

### Major Species

The South's varied climate and site conditions contribute to the region's large number of tree species. Of the 400 or so woody plants species in the South, more than 125 are considered commercially important. Overall, pines are the most important commercial tree species in the South. Currently, most forest industries depend on southern yellow pines to produce pulp, lumber, poles, plywood, oriented standboard and other products. The four major species of pine used are loblolly, slash, longleaf and shortleaf. Bald cypress is also an important conifer in the Southeast but is restricted to bottomland, pond or swamp areas of the Coastal Plain.

Oaks are the major commercial hardwood species. Most important are white oak, northern red oak and southern red oak. Yellow-poplar and sweetgum are important hardwood species used by the furniture industry and in veneer manufacturing. Blackgum and water tupelo are important in veneer manufacturing. Sycamore and cottonwood are also commercially important. Recent advances in product development and use have increased the demand for low quality hardwoods for use in composite panels and paper production.

### Major Forest Types

Seven major forest types are depicted on the accompanying southern forest type map. Each type is named for the predominate tree specie or species in that group.

**LOBLOLLY-SHORTLEAF PINE**
This widespread forest type is found in most of the Piedmont and Upper Coastal Plain. Stands are 50 percent or more loblolly pine, shortleaf pine, and other southern pines (except longleaf or slash), singly or in combination. These forests may also include oak, hickory and gum.

**LONGLEAF-SLASH PINE**
This forest type occurs in the Lower and Middle Coastal Plain. Stands are 50 percent or more longleaf and slash pine, singly or in combination. Other trees commonly associated with this type include other southern pine, oak and gum.

**OAK-PINE**
A forest type found primarily in the transition zone between the Piedmont and the Mountain and Valley areas, it represents a later stage of plant succession throughout the region with more tolerant oak species replacing pine. Stands are 50 percent or more hardwood, usually upland oaks, with southern pine making up from 25 to 49 percent of the stand. Other commonly associated trees include gum and hickory.

**OAK-HICKORY**
This is the primary forest type of the Mountain and Valley areas. Stands are 50 percent or more upland oaks and hickories, singly or in combination. Southern pine

or redcedar make up less than 25 percent. Gum, yellow-poplar, elm and maple are common associates.

**OAK-GUM-CYPRESS**
This forest type is found primarily along major river and stream bottoms and swamps of the Coastal Plain and Mississippi Alluvial Valley. Stands are 50 percent or more tupelo, blackgum, sweetgum, oak and southern cypress, singly or in combination. Southern pine make up less than 25 percent of the stand. Other trees commonly associated with this forest type include cottonwood, willow, ash, elm, hackberry and maple.

**CEDAR**
Found in the Central Highlands of Tennessee, 25 percent or more of these stands are redcedar, with less than 25 percent southern pine. Oak and hickory are common associates.

**WHITE PINE-HEMLOCK**
Limited to sites in the Appalachian Mountain chain, these stands contain 50 percent or more eastern white pine and hemlock, singly or in combination. Common associates include oak and yellow-poplar.

**Seed Orchard Production**

To supply the demands of nursery production for reforestation efforts, over 12,000 acres of seed orchards are in operation across the South. Tree improvement programs began when selected forest stands were set aside as seed production areas. These areas were rogued of inferior species and trees lacking desirable characteristics. Later, seed orchards were established from grafts of trees with superior traits. Progeny from these orchards have been planted to evaluate their growth, form, yield and disease resistance. Progeny test data is then used to refine selections. At present, loblolly and slash pine seedlings are grown from genetically improved seed produced in managed seed orchards. Much of the seed for longleaf pine and many hardwoods still comes from seed production areas, although improvement programs are ongoing.

These valuable seed orchards are managed to insure development of high quality seed. Insect pests that damage seed and cones are monitored, and insecticides are applied when damage thresholds are reached.

**Tree Nurseries**

More forest acres are planted annually in the South than in any other region of the nation. In 1996, the 1.83 million acres planted to trees in the South accounted for 76 percent of the nation's total tree plantings. To support this tree planting effort, southern forest nurseries produce more than 1.2 billion seedlings annually, representing 79 percent of all forest tree seedlings produced in the U.S. Forest nurseries employ the latest techniques available to produce quality seedlings. Production of quality seedlings requires the use of fungicides, herbicides, and insecticides in conjunction with other cultural activities as part of an Integrated Pest Management program.

## PRINCIPLES OF FOREST PEST MANAGEMENT

Interest in protecting forests from insect, disease, weed and vertebrate pests has increased in recent years. This has come about largely because of:

1. increased awareness of the destructive capacities of pests;
2. the heavy toll they take on supplies of commercial and recreational timber;
3. environmental concerns;
4. effects on threatened and endangered species; and
5. availability of new, specific pesticides.

Forest managers have come to realize that much of the damage caused by pests could have been avoided. With adequate knowledge of pest identification and biology, combined with good forestry management practices, it may be possible to prevent or at least reduce losses due to pests. Trees in a vigorous condition are much better able to withstand damage by pests than trees already under stress.

We have learned that using a combination of prevention and control methods is the best approach to pest prob-

lems. The planned strategy of combining the best methods is called *Integrated Pest Management* (IPM) and is discussed in the "Applying Pesticides Correctly" core manual. Pest management should be a part of an overall forest management plan. The need for pest control treatments can often be minimized through wise, long-term forestry practices. The pest control method(s) chosen will depend upon the kind and amount of control necessary, balanced with costs and benefits within legal, environmental and other constraints. The most important principle of pest control is to use a control method only when necessary to prevent unacceptable levels of damage. Even though a pest is present, it may not be necessary to control it. It may cost more to control the pest than to cover damage or losses.

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 will potentially be affected? What will be the longterm impact of these organisms? Does the organism cause permanent or only temporary damage? Insects such as the southern pine beetle damage the cambium layer and introduce fungi that almost always cause tree death. In contrast, many foliage feeding insects cause one-time defoliation from which the tree can recover. Most trees can withstand complete one-time defoliation without significant longterm impact on tree health. However, an organism that has the potential to cause multiple defoliations (such as the gypsy moth) can have a much more detrimental impact on tree and forest health.

Before choosing a control 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 control 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 control practice(s) and keep accurate records.

If other management options do not yield satisfactory results, you may need to apply a pesticide to control an undesirable organism (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, seed orchards and nurseries, 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 control, and in pine release treatments. Insecticides are seldom used in general forest management because of high treatment costs and because some pest insects are highly mobile. Currently, the only disease control treatment common in general forestry field applications is for annosus root rot. Vertebrate animals are sometimes controlled through trapping or hunting, but repellents and poison baits may be employed.

**INSECTS**

Insects are the most destructive agents affecting forest and shade trees in the South. Tree roots, stems, limbs, needles, leaves of healthy or weakened trees, or logs waiting to be sawed into lumber are all subject to attack. Insects (Class: Insecta) are by far the most numerous animal life inhabiting the forest. They have become well adapted to their surroundings and occupy a wide variety of ecological niches. Although the majority of insect species are either beneficial or innocuous, some are exceedingly harmful. Insect outbreaks that cause economic damage to forests vary greatly in frequency, size and duration. Fortunately, most outbreaks

are small and short-lived, and usually consist of one or a few spots in a stand or region. Others, however, may expand and encompass hundreds or thousands of acres and can last for several years.

Managers can reduce the risks and incidence of insect attack by maintaining healthy and vigorously growing stands and trees. Research is being conducted to determine what conditions are conducive to forest insect outbreaks. This research may lead to improved control measures.

## Losses Caused by Forest Insects

These data are summarized from Special Bulletins published annually by The University of Georgia, College of Agricultural and Environmental Sciences, Department of Entomology, Insect Survey and Losses Committee. These figures have not been adjusted for inflation.

### Estimated Average Yearly Losses and Control Costs of Forest Insects in Georgia

| Rank | Insect | Cost of Control | Damage Loss | Total Cost |
|---|---|---|---|---|
| 1. | Southern pine beetle | $ 317,600 | $4,680,400 | $4,998,000 |
| 2. | Pine tip moths[1] | 916,000 | 2,310,000 | 3,226,000 |
| 3. | Defect & degrade[2] causing insects | 90,000 | 2,874,000 | 2,964,000 |
| 4. | Seed and cone[3] insects | 80,400 | 2,514,200 | 2,594,600 |
| 5. | Ips spp. beetles[4] and black turpentine beetle | 485,000 | 2,016,400 | 2,501,400 |
| 6. | Reproduction weevils[5] | 1,153,000 | 928,000 | 2,081,000 |
| 7. | Other insects[6] | 83,800 | 1,215,000 | 1,298,800 |
| 8. | Gypsy Moth | 94,000 | -- | 75,200 |
| | **Totals** | **$3,201,000** | **$16,538,000** | **$19,739,000** |

[1]Includes Nantucket pine tip moth and pitch pine tip moth.
[2]Includes carpenter ants, ambrosia beetles, lepidopterous oak borers, shothole borers and various other cerambycid, buprestid and scolytid beetles.
[3]Includes coneworms, seedworms, seed bugs and cone beetles.
[4]*Ips avulsus*, *I. grandicollis*, *I. calligraphus* and *I. pini*.
[5]Pales weevil and pitch-eating weevil.
[6]Primarily aphids, scale insects, sawflies and lepidopterous hardwood defoliators including eastern tent caterpillar, forest tent caterpillar, fall webworm, oak skeletonizer and various *Anisota* spp.

## Bark Beetles

Bark beetle populations vary tremendously between years and between locations. The important bark beetles in the South attack pines and belong to the Family Scolytidae. However, some species such as the native elm bark beetle *Hylurgopinus rufipes*, the small European elm bark beetle *Scolytus multistriatus* (Marsham), and the hickory bark beetle *S. quadrispinosus* Say are hardwood pests. The remainder of this bark beetle discussion will be about southern pine beetles, black turpentine beetles and *Ips* engraver beetles that attack southern pines.

Large numbers of attacking bark beetle adults can often overwhelm a tree's natural defenses, lay eggs and successfully initiate an infestation. After the eggs hatch, the grub-shaped larvae can girdle the tree by feeding under the bark. Blue-stain fungi are also carried on the bodies of most species and introduced into the tree during adult attack. Proliferation of these introduced fungi in the water-conducting tissues hastens the death of the infested trees.

Pines under stress are particularly susceptible to bark beetle attacks, especially if beetle outbreak conditions exist. Bark beetle attacks can be recognized by boring dust and pitch tubes on the outside of the bark, characteristic galleries under the bark, and adult beetles and larvae in the inner bark. After a tree is successfully attacked, the foliage fades from bright-green to yellowish-green to red. These "faders" are generally the first apparent sign of a bark beetle attack. Unfortunately, foliage color change often does not occur until well after the tree is dead and the beetles have completed their development and have left the tree.

Bark beetle brood development time ranges from 25 to 120 days, depending upon species and temperature. It is common for more than one species of bark beetles to infest individual trees. Since many other insects are associated with dead and/or dying trees, make positive identification of the insects before you take any remedial actions.

Reduce the potential for bark beetle attack by ensuring that trees are rapidly growing and healthy. Removing or treating lightning and storm damaged trees promptly and maintaining proper stand densities can reduce the likelihood of bark beetle attack. For specific management and control practices, contact your county Extension Service agent or State Forestry office.

**Southern Pine Beetle** - The southern pine beetle (SPB), *Dendroctonus frontalis* Zimmermann, is the most destructive of the eastern species of pine bark beetles (Figures 1-5). It is a small reddish-brown to black beetle, about 1/8 of an inch long. The rear end of the body is rounded. SPB normally infest boles of trees from the base to the crown, with initial attacks at mid-bole or higher. The life cycle generally requires 35-60 days to complete. There may be up to six generations per year. Small pitch tubes, usually less than 2 inch in diameter, are often present at the site of adult attacks.

**Figure 1.** *The southern pine bark beetles. Top to bottom:* ***Ips avulsus, Ips grandicollis, Ips calligraphus, Dendroctonus frontals*** *(SPB),* ***Dendroctonus terebrans*** *(BTB).*

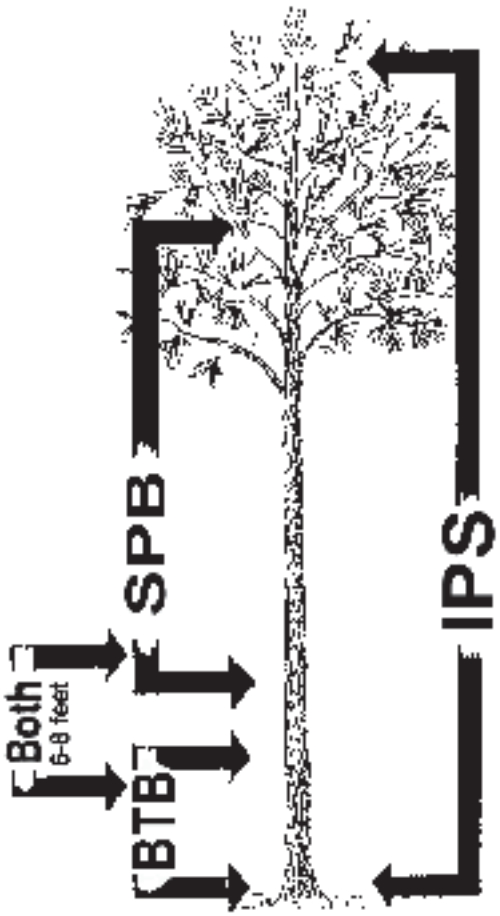



**Figure 2**. *Sections of the trunk which three types of bark beetles attack.*

Adult SPB bore directly through the bark and mate. The females excavate the characteristic S-shaped, criss-crossing egg galleries in the inner bark. Eggs, which are deposited in niches on either side of these galleries, hatch into small, legless grubs within 4-9 days. The grubs mine for a short distance before boring into the outer bark where they pupate. Galleries are usually filled with larval fecal material and boring dust. Soon after a tree is attacked, all the needles turn yellow and then brown. Drought seems to trigger major outbreaks of this insect. In addition to direct damage caused by the larval feeding, SPB introduce stain-causing fungi, which invade the tree and hasten death. **Once southern pine beetles have successfully infested a tree, no remedial treatments are available to prevent the death of the tree.**

**Black Turpentine Beetle** - The black turpentine beetle (BTB), *Dendroctonus terebrans* (Oliver) is the largest


**Figure 3.** *Southern pine beetle:* pine killed by beetle with blues stain fungus, a cross section of log


**Figure 4.** *Southern pine beetle: 'S' shaped galleries under bark*


**Figure 5.** *Southern pine beetle pitch tubes on loblolly pine*

of the major southern bark beetles (Figures 1-2, 6-7). It is 1/4 of an inch or more in length, with a rounded rear end, and is reddish-brown to black in color. Large purplish colored pitch tubes (50 cent piece in size) are often present at the site of adult attacks. BTBs attack

fresh stumps and living trees by boring through the bark and constructing galleries on the face of the sapwood where 50-200 eggs are laid in a group. BTBs attacks usually only occur on the trunks of trees up to a height of eight feet. After hatching, the white larvae feed on the inner bark. Unlike southern pine beetles and *Ips* engraver beetles, black turpentine beetles do not introduce blue stain fungi into the tree and developing larvae feed in "patches" rather than completely encircling the tree. However, when several broods occur at about the same height, the feeding larvae may completely girdle and kill the tree. Without prompt treatment, from 70 to 90 percent of the trees attacked by the BTB die. The BTB life cycle takes from 2 1/2 to 4 months, depending on the temperature. In the South, there are usually two generations and part of a third each year.

***Ips* beetles** - The four species of *Ips* beetles commonly found in the South (*Ips grandicollis*, *I. calligraphus*, *I. avulus*, and *I. pini*) vary from 1/10 to 1/4 of an inch long, and are yellowish, dark reddish-brown to black (Figures 1-2, 8-10). They are easily recognized by their scooped out posteriors which are surrounded by varying numbers of tooth-like projections. In hot weather, it may take as few as 25 days to complete one generation. Populations of these beetles increase rapidly during favorable conditions. *Ips* spots usually contain only one to a few trees killed, but under favorable conditions *Ips* can become epidemic and kill many trees. The fully grown, grublike larvae are yellowish-white and vary from 1/4 to 1/3 inch long. Gallery patterns are more or less Y- or H-shaped except for *I. avulus*, which deviates from these patterns. Small, white eggs are laid singly in small egg niches cut along the main tunnels. Larval feeding tunnels are usually filled with boring dust and frass (excrement).

Adults girdle trees quickly as they construct their egg galleries in the inner bark. The tree's death is usually hastened by the introduction of blue-stain fungi which


**Figure 6.** *Black turpentine beetle larval feeding patch*


**Figure 7.** *Black turpentine beetle pitch tube*


**Figure 8.** *Ips avulsus adult and larval galleries*


**Figure 9.** *Eastern fivespined Ips adult and larval galleries*

blocks the flow of sap. Small reddish pitch tubes are frequently the first sign of an attack. These tubes are usually absent in trees suffering from drought. **As with SPB, once *Ips* beetles have successfully infested a tree, the tree cannot be saved!**


**Figure 10.** *Ips pini gallery on small pine*

**Pine Bark Beetle Control**

Several methods reduce the likelihood of expanded attacks by bark beetles. Most of these are based on good silvicultural practices to keep trees rapidly growing or by reducing stress on trees. Techniques currently used are:

- Prompt removal (and/or treatment) of trees damaged by lightning, storms or by construction
- Salvage removal
- Cut and leave
- Pile and burn
- Insecticide treatments
- Cut and spray
- Behavioral modifying chemicals

*Prompt Removal* of any damaged trees, whenever possible, significantly reduces the likelihood of successful bark beetle attacks. Since bark beetles are attracted to odors exuded from damaged trees, initial attacks in an area often occur on damaged trees. As the beetle brood matures and exits the infested tree, the infestation frequently expands to other trees in the area.

*Salvage Removal* is only feasible when a relatively large volume of wood is available and makes the operation cost effective for the logger. Prompt removal of dead and dying trees is essential to prevent significant degradation of the wood. Steps involved in a successful salvage removal operation include:

1. the removal of a 50-100 feet wide buffer strip of green uninfested trees around the most recently attacked trees;
2. removal of recently attacked trees containing developing beetle brood; and
3. removal of older standing trees from which the brood has already emerged.

*Cut and Leave* is best for controlling small spots of trees (10-50) when salvage is not practical or cost effective. Attacked trees and a border of healthy trees are felled toward the center of the spot. It is helpful to cut the limbs on the underside of the felled trees so that the trunks are lying on the ground. The increased sunlight and subsequent higher temperatures, along with increased humidity resulting from the trunks lying on the ground, are thought to cause high mortality of the developing brood.

In *Pile and Burn,* trees with live brood are felled, piled and burned. Although effective, this technique requires heavy equipment to pile the trees so that they can be burned. Additionally, managers must be aware of appropriate weather conditions and prescribed fire and smoke management issues.

*Insecticides* in bark beetle control are more preventative than corrective. Consequently, with the possible exception of the BTB which **does not** introduce blue-stain fungi into the tree, trees that have been successfully attacked by bark beetles cannot be saved by insecticide applications. However, bark beetles still in or under the bark can be killed by spraying the tree with appropriate insecticides to prevent spread of the attack. Additionally, non-infested high value trees, judged to be at high risk, can be sprayed with an insecticide as a preventative measure against attack. The area of the tree requiring insecticide treatment depends upon the insect species for which the application is being made. The appropriate area of the tree should be thoroughly wetted with the insecticide spray mixture.

Applications made for BTB only require that the lower 8-10 feet of the main bole be treated and can be accomplished with a small hand or backpack sprayer. **If applications are being made for SPB or any of the *Ips* beetles, spray to wet the entire bole of the tree from ground level up to the upper crown, including the base of large scaffold limbs.** On larger trees, this requires high-pressure sprayers for thorough coverage.

A *Cut and Spray* method may stop further spread of bark beetle attack. If beetle infested trees can be felled but cannot be hauled from the site or burned, they can be limbed and bucked into workable lengths. Once cut into workable lengths, the tree sections can be turned as they are thoroughly sprayed with an appropriate insecticide.

*Behavioral Chemicals* are being tested by researchers to develop SPB control tactics by manipulating the various chemicals that the beetles (and their natural enemies) use to orient, attack or disperse their populations. To date, these promising, nonpesticide-based tactics are not yet ready for large scale field implementation.

## Boring Insects

Included in this group are the insects that infest terminals, shoots, twigs and roots of living trees as well as those that obtain food and shelter from wood. Terminal and shoot insects are of particular importance in the initial stages of forest regeneration and early stand growth. These insects are also of great importance in forest nurseries and ornamental trees. We will discuss in detail the Nantucket pine tip moth, and the white pine and deodar weevils which are frequently encountered in and cause significant damage to pine stands in the South.

Other insects in this category damage or destroy trees that would otherwise produce quality lumber or other wood products. Most insects that cause this damage are borers, either adult or larval stages or both. Most borers are secondary invaders, attacking bark and wood of trees that are seriously weakened, dying, or recently cut. Carpenterworms, ambrosia beetles, oak clearwing borers, metallic wood borers, Columbia timber beetles and southern pine sawyers are some of the pests that cause damage in this category. Trees attacked by these pests are usually scattered so that most control measures are difficult and not economically feasible. Additionally, there are several species of insects that attack, infest and damage wood and wood products that are discussed in the Wood Treatment manual and in other manuals devoted to Pest Control Operator training and are not covered in this manual. Included among the wood product pest group are certain beetles in the family Cerambycidae (notably, the old house borer *Hyloupes bajulus)*, ambrosia beetles (Scolytidae and Platypodidae), and the powderpost beetle complex (includes members of the Families Lyctidae, Anobiidae, and Bostrichidae).

The **Nantucket pine tip moth**, *Rhyacionia frustrana* (Comstock), and its close relative the subtropical pine tip moth, *R. subtropica* Miller are widely distributed in the southern states (Figures 11-13). The importance of pine tip moths on pine and Christmas tree plantations and nurseries varies widely with tree species, host vigor and environmental factors. Heavily infested trees may be severely stunted or deformed, but mortality is rare. Generally, the tree grows out of the susceptible stage within a few years. All species of pines are attacked except white and longleaf pines, but slash pine is rarely attacked. Loblolly, Virginia and shortleaf pines are most susceptible.


**Figure 11.** *Nantucket pine tip moth larva feeding at base of needles*


**Figure 12.** *Nantucket pine tip moth damage to pine terminal*

The adult moth is mixed gray and shiny copper-colored, with a wingspan of about 1/2 inch. The young larvae are light cream- colored, while mature larvae are light brown and approximately 3/8 inch long. Pupation occurs on the tree in the damaged terminal. Adults begin to emerge on warm days in early spring and begin laying eggs in a few days. Eggs are deposited on needles, stems, developing tips or buds. After hatching, larvae first feed on needle fasicles, then bore into terminals and lateral shoot buds, and finally into stems. The larval period lasts from two to four weeks. There are usually three to four generations per year.

Insecticide spraying for tip moth control has not been a general practice, except in Christmas tree plantations, seed orchards, forest nurseries, and research and progeny tests. However, tip moth control is increasingly becoming a component of intensive short-rotation pine plantation management. Effective control requires that insecticide applications coincide with egg hatch and larvae emergence. Trapping or monitoring moth emergence to predict egg hatch and larval development is the critical element in a tip moth control program.


**Figure 13.** *Nantucket pine tip moth on loblolly pine needle*

## Weevils

The snout beetles (Coleoptera: Curculionidae) are a diverse and abundant group of insects. Many weevils are important destructive pests of agricultural, horticultural and forest crops. Weevil larvae are creamy-white and legless, with brown head capsules. Adults are hard-bodied, cylindrical beetles with a pronounced "snout" that contains hardened, chewing mouth parts at the end.

The two most common species of boring pine weevils in the South are the white pine weevil, *Pissodes strobi* (Peck), and the deodar weevil *Pissodes nemorensis* Germar. Weevils in the genus *Curculio* attack the seeds of nut-bearing trees, most notably acorns, but several species are important pests on hickory, chestnut, and pecan. During certain years, the nut crop can be almost completely destroyed. In addition to the species listed, there are many other species of weevils that are important in forest environments.

The **white pine weevil** is the most serious pest of eastern white pines in the South (Figures 14-15). This weevil can also feed on and reproduce on a variety of spruce and pine species. Adult weevils are 1/6 - 1/4 inch long, brownish and marked with irregular gray-white patches. Adults overwinter in litter under the trees. The adults emerge from hibernation in the spring and begin feeding


**Figure 14.** *White pine weevil adult*

on cambial tissues of the main stems of the host plant, usually within 1 inch of the terminal bud. The female lays eggs in feeding pits on the terminals. After hatching, the larvae tunnel downward in the cambium. This feeding girdles and kills the leader. Mature larvae pupate in chambers formed in the wood. Adults emerge throughout the summer. Only one generation per year has been reported.

The first sign of white pine weevil attack is pitch flow from feeding punctures on the terminal shoots. Later the new growth appears stunted, and finally, the needles wilt and the terminal dies. Trees up to 3-4 feet tall may be killed. Dead terminals on larger trees are replaced by one or more branches of the topmost living whorl, resulting in crooked or forked stems. Management practices for the white pine weevil include: 1) mixed planting of white pines with hardwoods or planting white pines under hardwood cover; 2) planting only on soils where the hardpan is three or more feet below the surface; 3) selecting and pruning the least injured pines in preparation for later harvest; and 4) removal of less desirable pines from damaged stands. Drenching susceptible trees with pesticide sprays as adult weevils emerge from hibernation can provide some protection. Insecticide sprays are used to protect white pines grown for Christmas trees from damage.


**Figure 15.** *White pine weevil damage to terminal*

The **deodar weevil** attacks most species of pines and many introduced cedars (Figures 16-17). These weevils cause damage by feeding on young shoots in the crowns of sapling and pole-sized trees. Both adults and larvae kill terminals and cause branch-end flagging on pole-sized and small sawlog size trees. Adults are active and lay eggs all winter. The adult weevil is about 1/4 inch long, grayish-brown to dark brown with whitish spots on the wing covers. Adults are attracted to weakened, stressed or dying trees. They often breed in logging slash and trees killed by bark beetles. Adults chew holes and feed on the inner bark and wood of twigs and leading terminals. After chewing through the bark, females deposit eggs in the inner bark of host trees. Following egg hatch, the larvae feed beneath the bark much like white pine weevils, girdling and often killing the stem. Evidence of their presence is indicated by swelling of the bark over feeding areas. Pupation occurs in chip cocoons in the sapwood beneath the bark. Adults apparently become inactive (aestivate) during the summer months but appear again in the fall to feed on twigs and leading shoots. May is the month of greatest adult emergence.


**Figure 16.** *Deodar weevil pupa in chip cocoon*


**Figure 17.** *Deodar weevil adult*

## Chewing Insects

This grouping, based upon USDA Forest Service Pest Trend Impact Plot System, feeds on stems and shoots but does not include the leaf-eating insects, or borers. The more important members of this group in the South are the reproduction weevils which will be covered here.

**Reproduction Weevils -** The pales weevil, *Hylobius pales* (Herbst), and the pitch-eating weevil, *Pachylobius picivorus* (Germar), are very destructive pests of young pines (Figures 18-20). They feed and develop on all species of pines within their range. Adult pales weevils are 1/4 - 1/3 inch long with patches of yellow hairs appearing as bars across the wing covers. Pitch-eating weevils are slightly larger (1/3 - 1/2 inch) with yellowish spots on the wing covers. They spend the winter as adults in the soil. Overwintering adults emerge during the spring and feed on the bark of saplings and at the bases of seedlings. Most damage occurs in the spring and fall. These weevils feed at night and hide in the soil around the base of seedlings during the day. After feeding, females lay eggs on roots of recently cut, damaged or killed pines. Larvae burrow and feed on root tissue and later pupate in chip cocoons under the bark.

Damage or death of pine seedlings often occurs when adults of these weevils eat patches of bark from the stems. When feeding areas overlap, the seedling is girdled. Christmas tree plantations are sometimes seriously damaged by these weevils. The most practical and economical method of controlling damage is to delay planting in areas harvested after June for at least one year. If planting cannot be delayed, chemically control reproduction weevils by root dipping seedlings in an insecticide and kaolin clay mixture, top dipping of seedlings, or over-the-top spraying of seedlings prior to lifting in the nursery or after transplanting.


**Figure 18.** *Pales weevil adult*


**Figure 19.** *Pitch-eating weevil adult and feeding damage*


**Figure 20.** *Pitch-eating weevil adult feeding*

## Defoliating Insects

Included in this group are insects that eat leaves and needles. There is a diverse and broad array of insects that includes the many caterpillars, sawflies, leafcutting wasps, bees and ants, beetles and walkingsticks. Trees attacked by defoliators can be recognized by missing foliage and uneaten leaf parts such as veins and petioles. Additionally, many members of this group feed within a leaf, mining between the upper and lower epidermis. Defoliation reduces photosynthesis, interferes with transpiration and translocation within the tree. Light defoliation normally has little affect on the tree, but moderate-to-heavy or repeated defoliation can reduce tree

vigor. The impact that defoliation has on a tree depends upon the time of the year, the tree species, tree health, and whether defoliation occurs more than one time. It is important that the manager properly identifies the organism(s) involved and clearly understands the dynamics of both the forest stand and the insect involved before any management scenario is developed and implemented. Only a few examples of the insects that make up this diverse grouping are discussed here.

**Gypsy Moth -** When it is present, the European gypsy moth, *Lymantria dispar* (Linneaus), is one of the most destructive hardwood forest pests (Figures 21-23). A native of Europe, the gypsy moth was accidentally introduced into the U.S. in New England in the late 1800s and has gradually spread into at least 17 eastern states, as well as into other parts of the U.S. and Canada. The generally infested area now includes all of the northeastern states and portions of West Virginia, Virginia, Michigan and Ohio. Between 1982 and 1996 in the U.S., gypsy moth defoliation ranged from less than 1 to more than 8 million acres per year. Female European gypsy moths are incapable of flight but are prolific egg layers. Females lay eggs in masses in trees and on lawnmowers, outdoor furniture, mobile homes, recreational vehicles, firewood, building materials, doghouses, and other items left outdoors. New gypsy moth infestations occur through inadvertent transport of egg masses and pupae. Local infestations can spread as small larvae move from one site to another on air currents for distances of a few feet to several miles.

The female gypsy moth is heavy bodied, almost white with a wingspan of about 2 inches. The male is dark brown, with blackish bands across the forewings, and has a wingspread of about 1 1/2 inches. Full-grown larvae are from 1 1/2 to 2 1/2 inches long. Older larvae have yellow markings on the head, a brownish-gray body with tufts of hair on each segment, and a double row of five pairs of blue spots followed by a double row of six pairs of red spots on the back. Moths are harmless, but the caterpillars from which they develop are voracious leaf feeders of forest, shade, ornamental and fruit trees and shrubs. Large numbers of caterpillars can completely defoliate an area. A single defoliation can kill some softwoods, but it usually takes


**Figure 21.** *Gypsy moth larva*


**Figure 22.** *Gypsy moth females and egg masses*


**Figure 23.** *Gypsy moth defoliation*

two or more defoliations to kill hardwoods. Large infestations contain millions of caterpillars and can degrade aesthetic and recreational values of forests, parks and wooded homesites. The number of trees killed as a direct result of gypsy moth defoliation is relatively small, but many trees are weakened and become susceptible to secondary attack by other insects or plant diseases.

A U.S. Department of Agriculture Federal Domestic Quarantine (7CFR 301.45 gypsy moth) regulates transport of firewood, lumber, and many other outdoor items from infested areas to non-infested areas to prevent or reduce the likelihood of gypsy moth transport. A nationwide, cooperative state-federal monitoring program based on the use of large numbers of pheromone traps continues to monitor for accidental introductions of gypsy moths. The pheromone traps are effective in capturing the highly mobile adult males and are a good tool to monitor low-level gypsy moth populations. Control of newly developed "spots" detected by this monitoring program in southern states in recent years has been effective. Without this regulatory action, the gypsy moth would undoubtably infest an area much larger than the current areas.

Despite the quarantine efforts, isolated infestations of gypsy moth have occurred in the southeast in North Carolina, Tennessee, Arkansas, and Georgia. As these isolated infestations were found, comprehensive eradication projects, as mandated by federal law, have been undertaken.

During the past 80 years, many people have tried to control gypsy moth populations by introducing parasites into infested areas with limited success. Ongoing research on the use of viral and fungal diseases show promise for controlling the gypsy moth. In particular, a fungus introduced on several occasions over the last 80 or so years, appears to have increased in virulence or otherwise become widespread and extremely effective on reducing gypsy moth populations in recent years. This fungus, *Entomophaga maimaga,* has been reported to have significantly reduced gypsy moth populations in much of New England and Pennsylvania. We can only hope that the impact of this fungus continues to increase.

Aerial spray programs of an approved insecticide are still an important component of gypsy moth control programs in infested areas (Figure 24). Large acreages of forests and urban ornamental trees in infested areas are treated aerially with chemical and biological insecticides each year to reduce potential damage by this pest.


**Figure 24.** *Spraying Bt. by helicopter for gypsy moth*

**Sawflies**

Several species of sawflies (Hymenoptera: various families) can be serious defoliators of conifers in both forest and plantation stands. Sawfly adults are small broad-waisted wasps. Larvae resemble caterpillars but are usually without hairs and have five or more pairs of fleshy prolegs under their abdomen (caterpillars normally have four or fewer pairs). Larvae of the more commonly found sawflies vary from 2/3 to 1 1/4 inches long, are usually greenish to dusky gray, and have conspicuous stripes or spots. Outbreaks occur periodically, sometimes over large areas, and can result in loss of tree growth and sometimes tree mortality.

The **redheaded pine sawfly**, *Neodiprion lecontei* (Fitch), is one of the more commonly found and most destructive sawflies in the Southeast (Figure 25-26). Red headed pine sawfly larvae are usually found on trees from 1-15 feet tall, where they feed gregariously on old and new needles and on tender shoots of these young trees. Full-grown, redheaded pine sawfly larvae are about 3/4 to 1 1/4 inches in length; have a reddish head capsule and a yellowish-white body marked with six rows of black spots. Many times a naturally occuring virus causes collapse of an infestation. Occasionally,

controls are warranted during heavy population peaks. Depending upon the size of the infestation, these treatments may be applied aerially or by ground equipment.


**Figure 25**. *Redheaded pine sawfly larvae*


**Figure 26**. *Redheaded pine sawfly adult female oviposition*

**Pine webworm**

The pine webworm, *Tetralopha robustella* Zeller, may become a problem in pine plantations (Figure 27). The adult moth has about a 3/4-inch wingspan. The basal part of the forewing is purple-black, the central part grayish, and the outer part blackish. Full-grown larvae are yellowish brown, with two dark brown longitudinal stripes on each side and are about 3/4 inch long. Pine webworms overwinter as pupae in the soil. Adults emerge in late spring to early summer and deposit eggs on the needles. Young larvae mine needles, while older larvae live in silken tubes that extend through webs of globular masses of brown, coarse frass. These webbing masses enclose the needles upon which the larvae feed. At first, the webbing masses may be only one or two inches long. The webbing mass may contain several larvae and increases in size as the larvae mature. Seedlings up to two feet tall can be completely defoliated. Infestations on larger trees can cause partial defoliation resulting in loss of growth and poor tree appearance.

Usually no controls are necessary unless extremely heavy populations are encountered or individual specimen trees are involved. Individual infestations can be destroyed by hand. If controls are required, the larvae are easily controlled by labeled insecticides, but good spray coverage and pressure are needed to penetrate the webs.


**Figure 27**. *Pine webworm damage*

**Fall webworm**—The fall webworm, *Hyphantria cunea* (Drury), can have two or more generations per year. Webworms enclose leaves and small branches in their light gray, silken webs (Figures 28-29). Fall webworm is known to feed on more that 100 species of forest and shade trees. In the eastern U.S., pecan, walnut, American elm, hickory, fruit trees, and some maples are preferred hosts. The moth is white with dark wing spots and has a wingspan of between 1.4-1.7 inches. Though the webs are unsightly, damage to most trees is considered to be insignificant and is usually of only minor economic importance as a forest pest. However, in areas where heavy defoliation occurs, including in pecan production areas, control measures may be needed.


**Figure 28**. *Fall webworm larva*


**Figure 29**. *Fall webworm webbing*

**Oakworms**—The three common species of oakworm found in the South are the orangestriped, *Anisota senatoria* (J.E. Smith); the pinkstriped, *A. virginiensis* (Drury); and the spiny, *A. stigma* (Fabricius). Oakworms occur throughout the eastern U.S., are voracious feeders, and when abundant quickly strip trees of their foliage. However, since defoliation usually occurs late in the summer or into the fall, their economic impact is relatively minor. Orangestriped oakworm larvae are black with eight narrow yellow stripes; pinkstriped oakworms are greenish-brown with four pink stripes; and the spiny oakworm is tawny with pinkish short spines. Larvae have a distinctive pair of long, curved "horns" on the dorsum behind the head.

**Eastern tent caterpillar--** The eastern tent caterpillar, *Malascoma americanum* (F.), is primarily an aesthetic problem (Figures 30-31). Species of the genus *Prunus* are preferred hosts, with black cherry being the preferred non-cultivated host. Full-grown larvae are between 2 to 2 1/2 inches in length, have black heads and long light-brown body hairs. The back has a light stripe bordered on each side with yellowish-brown and black wavy lines. The sides are marked with blue and black spots. Eastern tent caterpillar overwinter as eggs in shiny, dark brown masses around small limbs on host trees. Eggs hatch in early spring, and the larvae begin to construct a tent and enlarge the structure as they feed and grow. Chemical controls are usually not justified. Defoliated trees normally refoliate and suffer only minor growth loss.

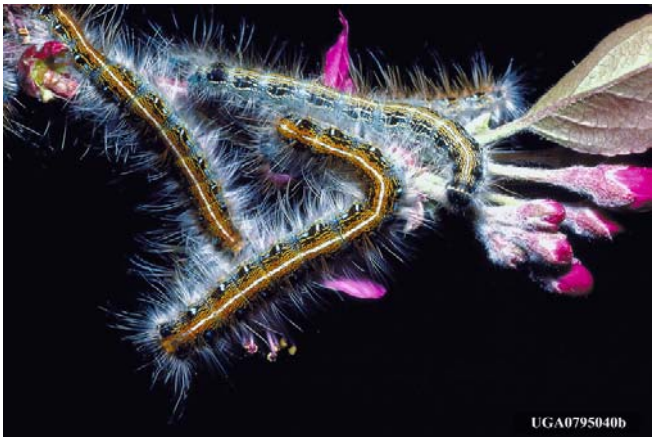



**Figure 30**. *Eastern tent caterpillar larvae*


**Figure 31**. *Eastern tent caterpillar tent in tree branches*

There are numerous other defoliating insects that will not be covered here.

**Sucking Insects**

This group of insects has piercing-sucking mouthparts which they use to pierce plant tissues and suck sap from the plant. Insects in this group that attack trees are in the Orders Homoptera and Heteroptera. In addition to these insects, many species of mites in the Class Arachnida: Order Acari also feed on plants. Only a few species of sucking insects kill forest trees directly. Among the observable symptoms of feeding by sucking insects are 1) discoloration of needles or leaves, 2) curled foliage, 3) honeydew and sooty mold on leaves, stems, twigs and other materials, 4) fine silk webbing on the needles and leaves, 5) premature leaf drop, 6) branch mortality, 7) oviposition scars made by cicadas and treehoppers, and 8) galls. In addition to their direct feeding damage, some sucking insects are vectors of plant diseases. Many of these insects are individually quite small and are frequently transported on nursery stock. As before, we will only discuss a few of the major forest pest species that make up this complex group.

**Scale insects**

A number of species of these small sucking insects are important in forest environments (Figure 32). Adult females lack wings, may not have legs, and are saclike with no definite body segmentation. Adult males are more insect in appearance, usually with one pair of wings and with a definite head, thorax and abdomen. Most scale insects produce a waxy substance that covers the body either as a shield-like structure or as a coating on the body surface. Natural dispersion is usually by windborne, first instar "crawlers" that are equipped with legs and can be quite mobile. In most cases, instars other than crawlers are generally sessile (do not move). The small size and cryptic appearance of many scale insects has greatly helped disperse many scales inadvertently as contaminants on plants transported during commerce. Scale insects damage plants by inserting their sucking mouthparts in plant tissue and ingesting large amounts of plant sap. Scale insects also excrete large amounts of honeydew which serves as a substrate for the growth of sooty mold. Plant deformation and toxin injury are produced by some species of scale insects. Natural enemies are frequently important in regulating scale insect populations. Scale insects occasionally become a problem in pine seed orchards where other pesticide applications have eliminated or reduced natural predator and parasite populations. Important groups of scale insects in forestry include mealy bugs, soft scales, armored scales and Kermes scales.


**Figure 32**. *Pine needle scale infestation on foliage*

The scale life stage most susceptible to chemical control is the first instar crawler stage. During this part of their life cycle, there is little or no waxy covering on the body. Attempts to control scale insects during other life stages are greatly hampered by the waxy covering on the insect's body and are often not very successful. To achieve control, monitor crawler emergence and time control efforts accordingly.

**Aphids**

Aphids are common pests on trees throughout the South. All southern pines are subject to aphid attack. They are soft-bodied, usually wingless insects less than 1/8 inch long. They may be pink, brown, black, whitish or greenish. The rate of development and reproduction of aphids is very rapid, producing many generations each year.

Aphids suck plant juices from the tender, succulent parts of plants. Heavy feeding causes stunting of terminal buds, and needles become distorted or stunted. Often the first sign of attack is the presence of many aphids on the branches. They excrete sweet, sticky honeydew which may attract many ants. A fungus, sooty mold

frequently develops on the honeydew and the branch or entire tree may appear black. Automobiles parked under heavily infested trees will frequently be covered with this sticky honeydew.

Chemical control of aphids is generally not economically justified except in cases of very high value or aesthetically important cases, such as Christmas tree plantations or nursery stock. Aphids can be controlled by an application of labeled insecticides when necessary.

**Balsam woolly adelgid -** The balsam woolly adelgid was accidentally introduced into the U.S. from Europe around 1900 (Figures 33-34). It has become a serious pest of natural Fraser fir stands in the southern Appalachians and thus causes considerable damage to the Fraser fir Christmas tree industry. The impact of this adelgid has been severe. Complete stand mortality, severe timber losses and reduced tree growth have been observed. This insect has killed millions of board feet of true fir timber in North America. Adults are blackish purple, roughly spherical in shape, and about 1/32 inch in length. The insect produces a covering of white wax threads on the surface of the tree's bole, limbs and buds. In the South, there are two to three generations of the adelgid per year. Orange-colored eggs are produced and remain under the adult's body until hatching. The newly hatched "crawler" is the only stage of the adelgid that is mobile. When the crawler begins feeding, it transforms into a first instar nymph and becomes stationary.


**Figure 33**. *Balsam woolly adelgid infestation*


**Figure 34**. *Balsam woolly adelgid crawler*

During the feeding process, the host tree is stimulated to produce abnormal wood that reduces the trees ability to translocate food and water. A heavily infested tree may die within 2 to 7 years. Chemical controls can be quite effective but are extremely costly and are usually limited to high value trees.

**Lace bugs -** Lace bugs, *Corythucha* spp., feed on the leaves of many tree species (Figure 35). Both the adults and nymphs feed on leaves, often resulting in chlorotic flecks or tiny chlorotic spots on the upper leaf surface. In addition to the presence of numerous nymphs and adults, the underside of leaves upon which lace bugs are feeding usually has numerous cast nymphal skins and numerous small black "frass spots" and black fungus. Heavily infested trees may be partially or fully defoliated, especially in dry weather. There may be several generations per year, and all life stages reside on the leaves of the host tree. Both the nymphs and the


**Figure 35**. *Sycamore lace bug adults*

adults feed by inserting their mouthparts into the leaf tissue and sucking plant juices. Nymphs are dark-colored and covered with spines. Adults have broad, transparent, lacelike wing-covers. The adults are flattened and are about 1/4 inch in length. Natural enemies are usually effective in controlling populations. Chemical controls are usually only used on high value shade and ornamental trees.


**Figure 36**. *Spider mite damage*

**Spider mites -** Spider mites are found throughout the South (Figure 36). A number of species are important pests of ornamentals and shade trees, as well as many other plants. Spider mites are less than 1/25 inches in length, and, depending upon the species, vary in color from yellowish, greenish, orangish, and reddish to red. Major symptoms of spider mite damage are silk webbing, cast skins, active mites, and discolored yellowish foliage. Spider mites spin very fine silk webbing as they move about. There are several generations of mites per year. During high infestations, infested foliage may be discolored, disfigured, or killed.

### *Insects in Seed Orchards and Forest Nurseries*

High value, intensively managed sites, such as seed orchards and forest nurseries, require aggressive forest insect control programs. A number of insects that are normally not considered economic forest pests can be quite damaging in seed orchards and forest nurseries. Pheromone traps are often used to monitor insect populations in these sites. Some of the major seed and cone insect pests are the southern pine coneworms, pine seedbugs, various sawflies and thrips.

**Coneworms -** Several species of coneworms (*Dioryctria* spp.) are highly injurious to seeds and cones of conifers (Figures 37-38). These insects infest all commercially significant pines as well as spruce, fir, hemlock, and cypress. The southern pine coneworm (*D. amatella*) infests cones, male flowers, shoots, and fusi-


**Figure 37**. *Southern Pine Coneworm larva, adult and damage*


**Figure 38**. *Webbing coneworm adult*

form rust cankers on a variety of southern pines. Adults have a wingspan of about 1 and 1/8 inches. The forewing is dark brown with contrasting white patches in zigzag lines running across the wings. Mature larvae are brownish to purplish above, pale whitish to greenish below and about one inch long. This species is frequently reported to cause heavy cone losses to southern pines.

The Heteroptera, the true bugs, contains two families that are significant pests of a number of conifer species. The coreid bugs (Coreidae) and the stink bugs (Pentatomidae) feed on the ovules and seeds of pines and conifers.


**Figure 39**. *Leaffooted pine seed bug adult*

**Leaffooted bugs -** Leaffooted bugs in the family Coreidae genus *Leptoglossus* are important pests of loblolly and shortleaf pines (Figure 39). Both the nymphs and adults are reddish-brown to gray and have long legs with a laterally expanded "leaflike" tibia on the hind leg. The adults are 2/3 - 3/4 inches in length and have distinctive whitish marks across the wings.

There are several generations produced each year. Nymphs and adults have piercing-sucking mouthparts that they insert into the conelets or cones to penetrate and feed upon the developing ovules and seeds. Attacked cones show no external damage symptoms, but damage to seed can be severe.

**Stink bugs -** Stink bugs in the family Pentatomidae emit a disagreeable odor when they are disturbed. The shieldbacked pine seed bug, *Tetyra bipunctate* (Herrich-Schaffer), is an important pest in southern pine seed orchards. The adults and nymphs are oval and have a humpbacked appearance. The adults are about 2/3 inch in length and are gray-brown to reddish-brown in color. There is only one generation per year. Nymphs and adults both have piercing-sucking mouthparts which they insert into cones to penetrate the seeds (Figure 40). Most of the damage occurs in late summer and fall, which results in poor seed viability and low yields of sound seeds.


**Figure 40**. *Stink bug nymph*

A number of insecticides are specifically labeled for and are used in seed orchards and forest nurseries. Ground-based hydraulic sprayers, airblast sprayers (mistblowers), and handheld compressed-air sprayers can be used to apply pesticides. Aerial applications are made with both helicopter and fixed-wing aircraft, equipped with either conventional or by ultra-low volume equipment.

## Gallmakers

When feeding on plant tissues, many insects and mites inject or secrete a substance into the plant that causes the plant to grow abnormal "galls" (Figure 41). Galls may be found on leaves, buds, stems, or roots. Plant galls are caused by a number of different animal and disease organisms, but the majority are caused by insects and mites. The greatest majority of galls are produced by cynipid wasps (Family Cynipidae), gall midges (Family Ceccidomyiidae), and eriophyid mites (Class Arachnida: Order Acari: Family Eriophyidae). How-


**Figure 41**. *Typical Oak Gall*

ever, other wasps, mites, flies, beetles, homopterans, and lepidopterans also produce galls. Each species of insect or mite produces a characteristic gall on a certain part of a specific plant. The host involved, the location, and the shape of the gall produced are extremely useful in identification of the causing species, since the actual organism itself is small or may have already vacated the gall.

Insect and mite galls are not considered economically important in forest stands. Gall makers are considered important pests on certain ornamental trees and shrubs and on some Christmas trees. Usually controls are not needed for gall makers but may be desired in some situations such as Christmas tree plantations and ornamental plantings.

## DISEASES

### Root/Butt Diseases

Pathogens that attack root systems may affect small feeder roots as with Littleleaf disease, or a pathogen like Annosum root disease can attack larger roots causing decay extending into the butt of the tree where lateral roots attach to the trunk. In general, root diseases are more prevalent on sites which have been altered by erosion, compaction, imperfect drainage, or other disturbances. Along with site factors, environmental stress, host characteristics, and interactions with other microorganisms lead to root disease complexes which may become prevalent in plantations.

**Littleleaf Disease -** Littleleaf is the most serious disease of shortleaf pine in the South (Figures 42-43). However, in localized areas, loblolly pine can also be severely affected. Other pine species are much less susceptible to littleleaf disease. As the name implies, littleleaf disease results in shortened, stunted yellow needles. Early symptoms are difficult to distinguish from nutrient and water deficiencies. As the disease progresses, the foliage is thinned; tufts of needles only remain on branch terminals; and twigs and branches die throughout the crown. Normal needle length of 3-5 inches is reduced to about 2 inch. Although cones may be abundantly produced, they will be very small and contain only a few viable seeds.


**Figure 42**. *Littleleaf disease on pine*


**Figure 43**. *Littleleaf disease* typical soil profile of susceptible site

Littleleaf disease is caused by a combination of poor soil-water drainage and subsequent attack of the feeder roots of pine by the fungus *Phytophthora cinnamomi*. The *P. cinnamomi* fungus is found throughout the growing range of shortleaf pines. The fungus requires free moisture to survive and reproduce. As new root-tips and very young feeder-roots are attacked and killed by the fungus, nitrogen uptake is reduced, resulting in slowed growth and yellowing of the foliage. Relationships between poor soil drainage and root infection confine the disease to heavier, fine-textured soils.

Stands are seldom affected prior to 20 years of age. The manifestation of the disease is most intense in stands more than 40 years old. Infected trees may survive for up to six years after first visible symptoms appear, although a few may die the first year. Infected trees rarely recover from the effects of the disease unless they can be fertilized, which is generally only practical in an urban situation.

Do not plant shortleaf pines on soils with poor internal drainage. The lack of oxygen in these soils prohibits regeneration of roots and restricts root development into the soil. When the available nitrogen is depleted in *P. cinnamomi* infested soil, littleleaf disease develops. Favor more resistant loblolly, slash and longleaf pine over shortleaf pine in areas susceptible to littleleaf disease.

**Annosum Root Disease -** Caused by the fungus *Heterobasidion annosum*, annosum root disease can infect all pine species in the South (Figures 44-45). Fungus fruiting structures (conks) may appear on the bark surface at the root collar area of the tree or stump. Spores liberated from these conks can cause local and long-distance spread of the fungus. Spores, which are air-blown to the surface of freshly cut stumps, germinate rapidly and infect the stump. Mycelium of the fungus grows into the stump root system and is transmitted through root contacts or root grafts to roots of healthy trees. Spores of the fungus have the ability to infect directly and are more prominent on stump roots than on roots of healthy trees. Roots damaged and exposed when plowing fire breaks or during road construction are susceptible to becoming infected as well.

Suspect annosum root disease if tree mortality begins the second or third year following thinning and continues for several years. Infected trees show a general lack of vigor, shortened needles and internodes, chlorosis and heavy cone production. However, infected trees frequently do not show the symptoms and may


**Figure 44**. *Annosum root disease pitch-soaked wood and sand*


**Figure 45**. *Annosum root disease; windthrown diseased trees*

fall over before any injury is noticed. Decline can be rapid or may take several years. Examine lateral roots for pitch-soaking and white, stringy decay of terminal considered a high-hazard site for annosum. Obtain soil survey maps to study soil for characteristics of texture and drainage. Interpret these results as indications of a low- or high-hazard site. When soil maps are not available, roadside cuts offer clues about the soil profile. When 50 percent or more of the land area is determined to be high-hazard, the entire stand should be managed as a high-hazard site.

In high-hazard areas, thin the stand only in the summer as high summer temperatures limit spread and viability of the spores. Stumps may also be treated with borax immediately following harvest. If mortality continues for five years after the first thinning, clearcut the stand and regenerate.

**Stem Decays/Cankers**

Gall and canker forming pathogens pose serious problems in forest management through tree loss and stem quality degrade. The most serious problems occur in southern pines, although canker diseases of hardwoods cause significant losses as well. Chestnut blight, caused by *Cryphonectria (Endothia) parasitica,* eliminated

American chestnut in North America in less than 50 years after it was introduced from the Orient in 1900. Other frequently observed hardwood canker diseases include, most hypoxylon dieback (*H. atropuntatum*), nectria canker (*N. galligena*), strumella canker (*Urnula craterium*), and fusarium canker (*Fusarium* spp.). These hardwood cankers seldom result in direct mortality but cause substantial stem quality degrade and increase stem breakage. Most hardwood canker diseases occur when individual tree vigor declines following environmental stress and/or mechanical damage, such as fire, wind damage, or logging damage.

**Fusiform Rust -** Fusiform rust of slash and loblolly pine causes extensive economic loss annually in pine stands (Figures 46-48). These losses are compounded by the impact fusiform rust has in nurseries and young plantations.

The most easily recognized symptom is the spindle shaped canker on pine branches or main stems. In early spring these swellings appear yellow to orange as the fungus produces powdery spores. Older stem cankers may become flat or sunken as host tissue is killed. Cankers often girdle trees; wind breakage at the canker is common. Spores of the fungus *Cronartium quercum* f. sp. *fusiforme* produced on pine infect oak leaves. Brown, hairlike structures are produced on the underside of the oak leaves in late spring. Spores are produced, which in turn reinfect pine trees, completing a typical rust cycle.


**Figure 46**. *Fusiform rust gall*

Disease control in pine stands is primarily achieved by removing infected trees during thinnings and using genetically superior seedlings. On high-hazard sites, plant resistant species using locally or regionally improved selections. Plant pines within their natural range, especially slash pine. Plant only disease-free nursery stock.

On bare, high-hazard sites, use a minimal level of site preparation to give satisfactory plant survival and growth. Destroy present host oak populations by burning, herbicide treatment or girding large residual oaks. Prevent resprouting of oaks. Limit the size of planting blocks to increase variation in age classes and plant material. Planting density can be adjusted to compensate for random rust infection and mortality but only to the extent that growth and yield are not affected before scheduled thinning.


**Figure 47**. *Fusiform rust infected seedlings*


**Figure 48**. *Fusiform rust pycnia*

Delay fertilization of slash and loblolly until the 10th year in regions of moderate or high-hazard. In low-hazard, flat-wood sites, growth response of slash pine to fertilizer will offset the rust impact.

When the stand is 3-5 years old, estimate rust incidence to determine future management policy. If disease incidence is high, consider sacrificing the stand early to replant with resistant plant material. Burning will help keep intruding oak hosts under control. Potential losses in older, heavily infected stands can be reduced by presalvage harvesting of rust infected trees. Burn after harvesting.

Nurseries should be located in low-hazard areas. Host oaks and infected pines should be eradicated from the area before establishing a nursery. Apply protective fungicides according to the label. Since warm, moist conditions are required for fungus infection, irrigate only during the middle of the day during the rust season. This allows the foliage to dry, rather than remain wet overnight.

**Pitch canker -** The pitch canker fungus, *Fusarium subglutinans* (Wollenweb. & Reinking), causes growth loss and mortality to many pine species including Virginia, slash, loblolly, shortleaf and longleaf (Figures 49-50). Pitch canker is characterized by copious pitch flow and pitch-soaked wood. Shoot cankers result in dieback, characterized by wilting and killing of the crown. Needles on infected shoots turn yellow to reddish-brown, later turning greenish-brown to dark gray.


**Figure 49**. *Pitch canker: stem canker*

Cankers on trunks and large limbs are perennial, while cankers on shoots are usually annual. Infected pole-size trees usually have annual shoot cankers and may die from extensive infections. Less affected and younger trees may not be killed but may suffer reduced growth


**Figure 50**. *Pitch canker fungus growing from seed*

and loss form. Infected seedlings exhibit yellow-green to reddish-brown needles and wilting foliage. Pitch-soaked lesions occur at and just above the soil line. Infected seedlings will inoculate healthy stock when inter-mixed during handling and transit. Take care to cull out pitch canker infected stock during transplanting. Infected seedlings are usually killed by the disease. Systematic removal of infected trees reduces inoculum sources and fire hazard, as well as providing growth space for other trees.

**Foliage Diseases**

Maintaining optimum leaf area is critical to tree health, growth and yield. Premature shedding of infected foliage is a defense mechanism which isolates and removes the attacking pathogen. However, repeated loss of effective photosynthetic leaf area from foliage diseases reduces growth and yield, predisposing trees to damage by secondary agents such as insects and environmental stress.

**Hardwood Anthracnose -** Numerous hardwoods are susceptible to anthracnose (*Apiognomonia spp.*) which may only cause lesions on foliage or may invade and kill

leaves, twigs, and branches. Anthracnose is common throughout the South and is most prevalent on sycamore and oak (Figures 51-52). Initial infection occurs in the spring during cool wet periods following leaf emergence, most commonly from mycelium that over-wintered in previously infected twigs on the host tree. Severe infections occur when temperatures are below 50° F for two weeks following leaf emergence. The infection enters the leaf and may grow into the leaf petiole and twig; and as twigs are girdled, dieback occurs. A canker may form which will girdle twigs in the following years. Necrotic areas develop along the veins and midrib of the leaves. Deformed blighted leaves may remain on the tree, but generally they are shed as the infection spreads over the leaf. As leaves, twigs and shoots die, complete crown defoliation can occur in the spring, but this is generally followed by a second leaf flush. Secondary infections can occur throughout the growing season when moisture is present.


**Figure 51**. *Oak anthracnose leaf symptoms*


**Figure 52.** *Sycamore anthracnose leaf blight*

In intensively managed sycamore plantations, use wide spacing to increase airflow between trees to aid in drying to reduce secondary disease cycles. Fungicide sprays may be applied at bud break and during early leaf development to provide protection for trees in plantations and ornamental settings.

**Needlecast -** Needlecast (*Lophodermella* spp.) is a very common disease of conifers throughout the southern United States. The disease rarely causes significant economic impact on forest trees although there is undoubtedly some reduction in growth associated with premature loss (cast) of foliage (Figure 53). Severe needlecast, in combination with other stresses, may contribute to vulnerability of trees to bark beetle attack.

Infected needles develop chlorotic spots beginning in winter or early spring that rapidly turn tan to reddish-brown from their tips. Characteristic black, raised football-shaped fruiting structures form on the infected needles. Thinning of the crown may result from needle drop of infected needles, leaving tufts of green uninfected needles at the branch tips. Needle cast symptoms rarely affect the entire needle. At maturity, these fruiting structures discharge spores that can infect healthy foliage.

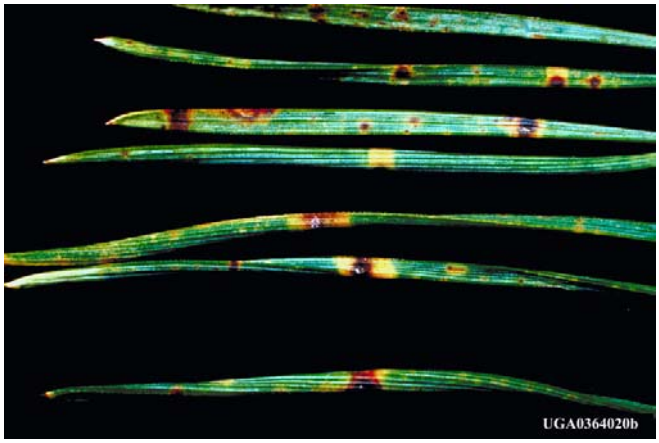



**Figure 53**. *Needlecast close-up of fruiting bodies*

Control is seldom feasible under forest conditions. In nurseries, shade trees and Christmas tree plantings, recommended fungicide applications may be economical.

**Brown Spot -** The most serious needle disease of longleaf pine is caused by the brown spot needle fungus, *Mycosphaerella dearnessii* (*Scirrhia acicola)*.

Infected needles in the early stages are irregularly yellow to brown spotted, with green tissue in between the spots. Needles are eventually killed by the girdling action of the fungus. Longleaf pine seedlings can be seriously damaged. Severe needle blight on young seedlings can increase the length of time it takes longleaf pine to grow out of the grass stage. The disease affects


**Figure 54**. *Brown spot: prescribed burn for control*

both planted and natural seedlings in the field. Brown spot can be controlled in nurseries by spraying with an approved fungicide. Prescribed burning can control the disease in longleaf pine seedling stands (Figure 54).

## FUNGICIDES

Disease control measures and fungicide applications in most forest situations are not usually cost effective. Fungicides are recommended in nursery production to protect these high volume seedlings from infections. Seeds are generally treated with fungicides prior to planting to inhibit fusiform rust and soil-borne damping-off fungi.

## VERTEBRATE PESTS

Several kinds of mammals and two kinds of birds sometimes damage living pines in the South. Their damage may vary from insignificant to serious. The mammals—deer, rabbits, squirrels, and other rodents—are the most serious pests. Mammals prefer to feed on plant materials that have been fertilized and have 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 for control harvests outside of normal hunting season and bag limits. Check state and local regulations before acting.

**Rabbits -** Rabbits commonly found in the southeast are cottontail rabbits, marsh rabbits and swamp rabbits**.** Nearly all southeastern forest habitats have at least one species of rabbit present. Rabbits prefer brushy vegetation that offers ample cover for hiding. Although rabbits are not normally destructive to well-established forest trees, they can 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. Deer have only upper front teeth and must pinch and pull stems, which leaves a broken end. 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 reduce rabbit numbers in damage areas. Removing brush piles and other cover areas may be effective in reducing high rabbit populations.

**Deer -** The most serious deer damage occurs from browsing on seedlings in nurseries and in young plantations. Deer frequently damage saplings by rubbing them with their antlers (Figure 55). This rubbing behavior, which may remove the bark, is usually associated with


**Figure 55**. *Slash pine rubbed by deer*

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 in effect.

**Tree Squirrels -** Tree squirrels, including the gray squirrel and the fox squirrel**,** are known to 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 due to 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. They also girdle stems and fell trees (Figure 56). 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 necessary.


**Figure 56**. *Beaver-felled tree*

**Cotton Rats -** Cotton rats have medium brown, grizzled fur and are about 8-10 inches long, including the tail. They are known to chew the bark from young pines up to a height of about 10 inches. This damage is sporadic and occasionally serious in 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 Mice -** Pine mice are small, short-tailed brown mice 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. They chew the bark from roots below ground and stems of saplings up to a height of about four inches.

**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 by their damage to large roots. Pocket gophers are not usually a pest in forest conditions.

**Woodpeckers -** Two kinds of woodpeckers may peck holes in live trees. The yellow-bellied sapsucker makes horizontal lines of small holes on many kinds of trees (Figure 57). The bird returns periodically to freshen the holes and feed on the sap welled up in them. The


**Figure 57**. *Yellow-bellied sapsucker adult and damage*

red-cockaded woodpecker, an endangered species, makes its nest by excavating a cavity in large pines exhibiting old growth characteristics, frequently in trees with red heart disease. Neither of these woodpeckers does significant damage under usual forest conditions, and both are protected by state and federal laws.

## VEGETATION CONTROL

Weeds are unwanted vegetation that interferes with land management objectives. They are obstacles to regeneration and optimum crop growth and development. Weeds compete with crops for moisture, nutrients and light. They can be classed as weed trees, brush, vines, and herbaceous weeds.

**Weed Trees** - Weed trees are undesirable hardwoods and conifers. They include deformed and defective or undersized individuals of both commercial and non-commercial species. Large weed 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** - 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. It 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** - Vines include greenbriar, Japanese honeysuckle, wild grapes, kudzu and other plants with climbing or creeping stems. All of these grow well on good forest sites. They drag down tree branches and crowns, and compete with desirable trees for light and nutrients. Vines have vigorous sprouting habits and are some of the most difficult weeds to control.

**Kudzu** is a serious weed pest in tree plantations and natural stands and is a threat to mature as well as developing stands and all regeneration. Repeated herbicide applications are essential for control. This vine spreads


**Figure 58**. *Kudzu vine*

so rapidly it can take over the site again in 2-3 years if a single root crown is left alive (Figure 58). Follow-up treatments must be made for one or more years after initial treatment. Kudzu's ability to resprout following treatment varies with the stand age, root size and plant vigor. Old stands may resprout for several years.

**Herbaceous Weeds** - Herbaceous weeds retard seedling growth in new plantations and natural stands. Tree seedlings competing with herbaceous weeds may develop poorly or die, especially in time of drought. Herbaceous weeds also create favorable cover for tree damaging animals such as mice, gophers 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 weeds. Plants are controlled by herbicides that act on the plant's 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 unlaw-

ful 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 classed as contact herbicides and translocated (systemic) herbicides.

**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.

**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 activity 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 eight modes of action describe the different ways in which forest herbicides can affect (and control) plants.

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

1. **Cell Membrane Disrupter** - Oxyfluorfen, Paraquat
2. **Respiration Inhibitor** - MSMA
3. **Photosynthesis Inhibitor** - Hexazinone, Simazine, Atrazine
4. **Growth Inhibitor** - Pendimethalin
5. **Lipid Biosynthesis Inhibitor** - Fluazifopbutyl, Sethoxydim
6. **Growth Regulator** - Dicamba; 2,4-D and 2,4-DP; Picloram; Triclopyr
7. **Amino Acid Synthesis Inhibitor** - Glyphosate, Imazapyr, Metsulfuron methyl, Sulfometuron methyl
8. **Pigment Inhibitor** - No forestry chemicals

**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 things.

Before making a pesticide application you should:
- know the pest to be controlled;
- be familiar with pesticides available for use;
- determine if a 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. wet lands, streams, houses, etc.) and organisms (such as livestock, wildlife and any threatened 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 environ mental conditions; and
- always read and follow label instructions.

## Environmental Concerns

The forest manager must be acutely 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 and wash off/ 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 formulations and their application methods.
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.

*Directed***:** Aiming the pesticide at a specific portion of a plant.

*Foliar:* Application to the leaves of plants.

*Over-the-top:* Application over the top of the crop trees.

*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.

*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.

Some of the terms that describe the purpose or timing of pesticide applications in forestry include:

*Cut surface:* Includes trunk injection, frill, frill-girdle, girdle and cut stump treatment.

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

*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.

*Plantation weed control:* Using herbicides for herbaceous weed control to ensure survival and rapid growth of planted tree seedlings.

*Postemergent:* Used after the crop trees or weeds begin to grow (emerged).

*Preemergent:* Applied before seedlings or weeds begin to grow (emerge) in the spring. This most often refers to applying a herbicide after the trees are planted, but before the weeds begin to grow.

*Preplant***:** Applied before the crop trees are planted.

*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 clearing or other vegetation control.

*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.

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.

**Application Methods**

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 woody release.

**Foliar**-Many forestry herbicides 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 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 becomes waxy and difficult to penetrate.

**Soil**-Soil-active herbicides 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 applied to the soil kill vegetation as seeds germinate or new plants grow through the treated ground. Season of the year, soil moisture, texture and pH, as well as organic matter and rainfall, greatly affect soil-active materials.

**AERIAL APPLICATION**

Aerial application is commonly used to apply pesticides in forestry. This is because tract size is often large, access is difficult; and the vegetation is often tall and dense. Large acreage 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 applications on 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 insure effective coverage of target vegetation. Water-based formulations require 5 to 20 gallons per acre (GPA) with the higher carrier volumes necessary when treating multistory canopies and dense vegetation. Oil emulsions use carrier volumes of 5 to 10 GPA due to costs and deposition efficiency. Aerial applications for midstory and understory hardwood control requires 15 to 20 GPA to insure good coverage beneath closed pine canopies (Minogue 1996).

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.

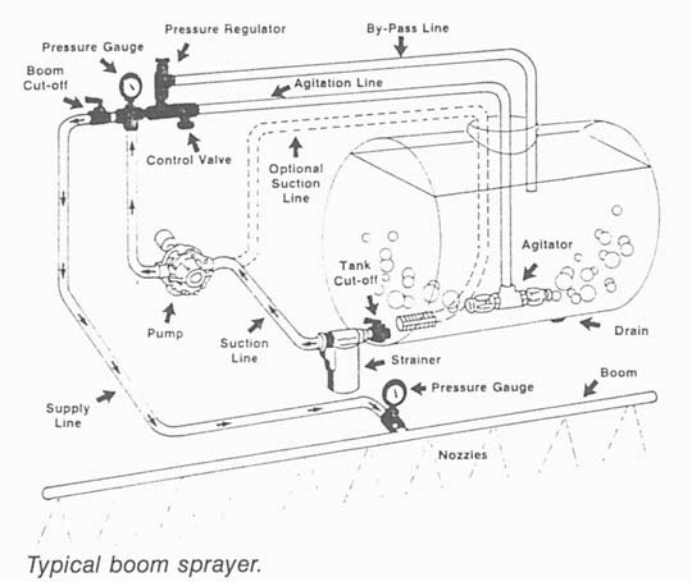
## MECHANICAL GROUND APPLICATION

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 and the sturdier ATV's (all-terrain-vehicles) 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 30 - 40 percent overlap. When it becomes



*Typical boom sprayer.*

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 type nozzles should be 15 - 20 gallons per acre (GPA) when operated at 22 - 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 four- to six - 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 APPLICATION

Manual applications are usually applied using backpack sprayers, mist blowers, hand-cranked broadcast spreaders, spotguns or one of various injection devices. The commonly applied manual treatments used in forestry are:

- Directed foliar sprays
- Basal sprays and stump treatments
- Tree injections
- Soil spots and granule/pellet applications

**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 pesticide 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** require that the lower 12 to 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** can control many woody plants including hardwoods up to 2 inches in diameter at breast height (dbh). 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.

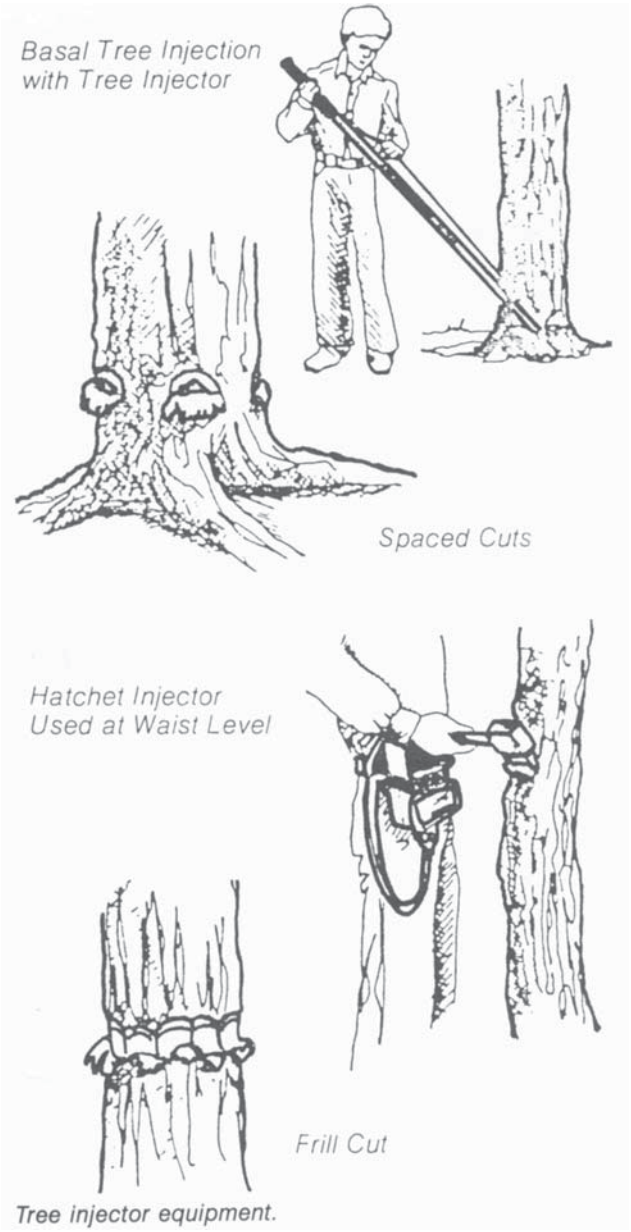
For stems less than 2 inches dbh, apply the stream of spray up and down single stems for about 6 to 8 inches, or spray across multiple stems creating a 2 to 3-inch-wide band. Direct the spray stream to smooth juvenile bark at a point about 6 to 24 inches from the ground. Stems that are beyond the juvenile 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 winter and early spring 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 if an ester herbicide formulation is used because pine injury may occur from vapor drift.

**Tree injection** 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*.

The *hack-and-squirt* 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 a 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.



Tree injector equipment.

*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.

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.

**Treating stumps** with herbicide can prevent resprouting of many species. This can be an effective, lowcost 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 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. Smaller stumps are usually completely wetted. 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 stream-line mixture. The mixture is applied to the outer 1-inch edge of the stump until runoff and to the base of any sprouts. Stump treatments within four hours of cut-

ting have been shown effective—the sooner the better. **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 or a spray-gun equipped with a straight-stream spray tip. The spotgun delivers a set amount while the spray-gun method requires training to judge the amount applied. A spotgun 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 spotgun can also be connected to a side-pack container.

**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 acutely 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.

The forest manager must be aware of both current and developing limits and restrictions dealing with pesticide use, and must use and enforce 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. It 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 species of beneficial forest insects. Some of these insects feed on forest debris and aid in its deterioration; others feed on organic matter in the duff and soil and contribute to improvements in soil fertility. Many others are parasites or predators of destructive insect species. Many insects are important food sources for birds and other small animals. Bees and certain other insects are important pollinators of many commercial crops as well as forest plants and trees.

Forest managers and pesticide applicators must be aware of these and other wildlife members of the forest environment. Pesticide labeling gives 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. Select the pesticide and application method that will have the least adverse impact and still get the job done.

**Prescribed Burning**

This 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 as well as other undesirable forest conditions. Prescribed burning is often an important part of most chemical site preparation treatments. Not only does it 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, EPA) to ensure their actions will not jeopardize the existence of any endangered species.

About 58 endangered species, or 17 percent of the total endangered species currently listed, occur in forest situations in the United States. Many of the pesticides presently labeled for use in forests are considered to have an adverse affect on one or more of these endangered species. These numbers doubtlessly will change over time, but they indicate there are many endangered species found in forest situations, and a number of pesticides will affect them. 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
- They 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.

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## APPENDIX

### 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 10 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 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 Table A1. Spacing of outlets or nozzles must be determined. Find this spacing in left column of the table and read the corresponding calibration distance. Example: for a 19" spacing, the distance would be 214.9 feet.

Step 2. Measure and mark calibration distance in a *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*.

Step 4. With 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 for calibration*.

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

**Table A1. 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=314.1.

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 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.

**Calibration Method for Boomless Broadcast and Band Sprayers -** 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 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 in the catalogs, use 80 to 85 percent of the wetted spray width.

Step 2. Using the spray width in Step 1, determine the calibration distance from the table 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 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*.

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

**Table A2. 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 13 feet swath, the calibration distance would be 340.3 divided by 13 multiplied by 10=261.8.

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 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.

**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 knapsack (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 A3.

**Table A3. 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 expressed in feet into 340.3. Example: For a 13" band the calibration distance would be 340 divided by 13/12=314.1.

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 boom, 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.

**Granular Herbicide Calibration -** The following procedure will give the pounds (total weight) of material applied per acre broadcast. This calibration procedure is based on 1/16 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 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 A4.

**Table A4. 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 swath width not listed, divide the swath width expressed in feet into 2722.5. Example: For 13 feet swath, the calibration distance would be 2722.5 divided by 13=209.4 feet.

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. 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.

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