PEST AND PESTICIDE MANAGEMENT ON SOUTHERN FORESTS

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PesticidePrecautionaryStatement

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key — out of the reach of children and animals — and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed them. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly and in accordance with all applicable Federal, State and local laws.

NOTE: Some States have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the U.S. Environmental Protection Agency, consult your State forestry agency, county agricultural agent or State extension specialist to be sure the intended use is still registered.

PREFACE

Federal law requires certification for all commercial pesticide applicators. The law also requires private applicator certification for the purchase or application of "restricted use" pesticides. The Environmental Protection Agency (EPA) has set minimum competency standards for certification of pesticide applicators. These standards include a practical knowledge of pest identification, pest control, label comprehension, pesticide laws, and environmental considerations. The certification of applicators is the responsibility of each individual State. To be certified as a commercial forestry applicator, most States require demonstrated competency in the general use of pesticides, with a specialization in forestry pesticides. This manual is a supplement, not a substitute, to the general-use training material. That material covers in detail the necessary information on pesticide labels, general application, and safety.

This manual is intended to provide the information necessary to achieve specialized certification for forestry pesticide applicators in the South. Additional certification may be required for other types of application used in or near a forestry site, such as aerial application and aquatic and right-of-way weed control. The section on applicator safety has been included for completeness, even though this is thoroughly covered in the general category training in most States. The materials provided here apply mostly to southern pines, although hardwood culture is addressed. Emphasis is placed on herbicide applications because most pesticides used in forestry are herbicides. Pesticide use in forest nurseries and seed orchards are not covered in detail because of their special situations. Specialists in nurseries and seed orchards receive special training in proper pesticide applications for their needs.

This training manual was prepared by an ad hoc committee appointed by the Southern Group of State Foresters. The committee members are pesticide specialists. Forest pesticide training manuals from each of the southern States were reviewed and the most pertinent sections were assembled along with additional information and further edited to produce a draft document. Further review and comments by each of the State forestry agencies was incorporated along with review by the Committee members.

This manual contains information useful to forest pesticide applicators and should be a part of their common knowledge if they are to be effective and safe in their applications. The Committee recommends that the appropriate agencies in each State carefully review this manual and incorporate appropriate sections in their training and reference materials. The Committee also recommends that testing material for each State be periodically reviewed so that applicators are tested on current methods and information.

The Committee would thank the extension specialists whose works have been incorporated in this regionwide compilation. Special recognition is owed to Dr. James B. Armstrong, Department of Fisheries and Wildlife, Auburn University, for providing the section on Vertebrate Animal Control. The editing of Christopher D. Kahle, Forest Pest Management, USDA Forest Service, Atlanta, GA, was crucial to the accomplishment of this task.

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INTRODUCTION

Society benefits greatly from the wise management of forest lands. The management objectives for southern forests vary considerably across the region, especially among ownerships. Management practices used by public agencies are usually aimed at balancing the outputs of wood production, wildlife, recreation, range, water, and mineral resources. Intensive forest management practiced by forest industry often attempts to optimize the production of wood products while managing the other resources of wildlife and water quality. Private management of woodlots and tree farms provides a source of income, recreation, and pride for many individual landowners.

Foresters manage groups of trees that are relatively uniform in species composition, size, and density called **stands.** Pests affect nearly every forest stand. **Pests** are plants, insects, diseases, or animals that hinder management objectives, especially regeneration efforts. Pests can increase costs of reforestation while reducing stand growth, product quality, and management efficiency. Pest outbreaks can mar the beauty of recreational forests, hinder plantings for soil stabilization, and complicate research studies.

Modem pesticides offer an effective and safe way to control many forest pests when used properly. However, it is not always practical or cost effective for a manager to use pesticides. Integrated pest management is an approach that carefully considers all management options, including pesticides, when attempting to minimize losses from pests. It is always beneficial to minimize pest impacts by wise management strategies that enhance stand vigor and by using pest-resistant growing stock. The effects of any treatment on the overall health of the stand and forest must be carefully considered.

Correct use of forest pesticides requires some knowledge of the forest ecosystem, the biology of forest pests, safe pest-control methods, and legal constraints. It requires knowledge of the pesticides and their application requirements. Safety of the applicator, the public, and the environment must be utmost in our considerations at all times.

The Forest Ecosystem and Stand Ecology

A **forest** is a complex biological community composed of plants, animals, insects, and microorganisms. The populations of organisms combine in a dynamic way with the environmental factors to form a **forest ecosystem.** Forest ecosystems are driven by the energy from sunlight. Only green plants are capable of capturing solar energy and converting it into sugars through the process of photosynthesis. All animals, insects, and microorganisms in a forest ecosystem depend on the energy fixed by plants from the sun.

The forest community and environmental factors are linked together through natural cycles. The water cycle — from rain, to soil, uptake through plants, and out through surface and ground waters or leaf transpiration — is powered by solar energy. The water cycle also drives much of the nutrient cycle. Nutrients are released into the soil when leaves, branches, and tree trunks decay in the upper soil zone, called the **decomposition zone.** Dissolved nutrients from this zone then cycle back to the plants, and are eventually returned to the soil in leaf and stem fall or washed out of leaves by the rain.

Pesticides can also be washed by rainfall into the decomposition zone, if they are not first broken down by sunlight to other less toxic molecules while on plant leaves. Ultraviolet light can break down pesticide molecules. Like other organic molecules, pesticides are also decomposed by microorganisms, water, and chemical reactions. Some are bound to soil particles until they decompose. Some more persistent pesticides may not fully decompose and may be carried by water in the soil to streams or possibly groundwater, especially when misapplication occurs. However, most pesticides are degraded to basic harmless molecules through natural processes.

Within a forest ecosystem, all organisms compete for sunlight, energy, water, nutrients, and space. The more of these resources that trees can gain, the faster and healthier they can grow. The

structure of a forest ecosystem is arranged according to how the member organisms receive and use these resources, mainly sunlight and water.

The natural change or maturing of a forest stand over time is known as **forest succession.** Forest succession begins with a major disturbance such as a fire or windstorm or, in managed forests, with harvesting (logging). These events create open areas for development of pioneer plants. **Pioneer plants** are those species that become established early in succession. Most grasses and forbs, which collectively are called herbaceous plants, are good examples of pioneer plants. They require full or nearly full sunlight to grow. Usually, they grow from numerous seeds already present in the soil or from seeds that have blown in with the wind. As forest succession proceeds, most pioneer plants are slowly shaded out by the developing forest.

Transitional species, usually comprised of light-demanding conifers such as the southern yellow pines, and hardwood species such as gums and maple, become established after disturbance. Left undisturbed: transitional species are slowly replaced by shade-tolerant species that are longer lived. A **climax forest** is one comprised of shade-tolerant trees that can regenerate within their own shade. Forest succession going to a climax forest is rarely completed over large acreage of forest land. Man's intervention or periodic natural disturbances frequently short-circuit the successional process and continuously "recycle" the forest to stands composed of transitional species. The expanses of southern pines are examples of the recycling of transitional species in the succession of a forest.

Forest managers work with natural succession to optimize timber production, or create recreational areas, or enhance wildlife habitat, or some other management objective. Proper pesticide applications can remedy certain unhealthy conditions in forest stands and prevent the spread and damage from insects and disease. However, because of the interrelationships within a forest community, controlling one component will influence others. Therefore, the forest manager must consider all the effects of a treatment when planning a control strategy to minimize undesirable effects.

Forest Types of the South

The South's varied climate and site conditions support a large number of tree species. There are about 250 different native tree species. Almost half are considered commercially important. The seven major forest types in the South are shown in figure 1. They are:

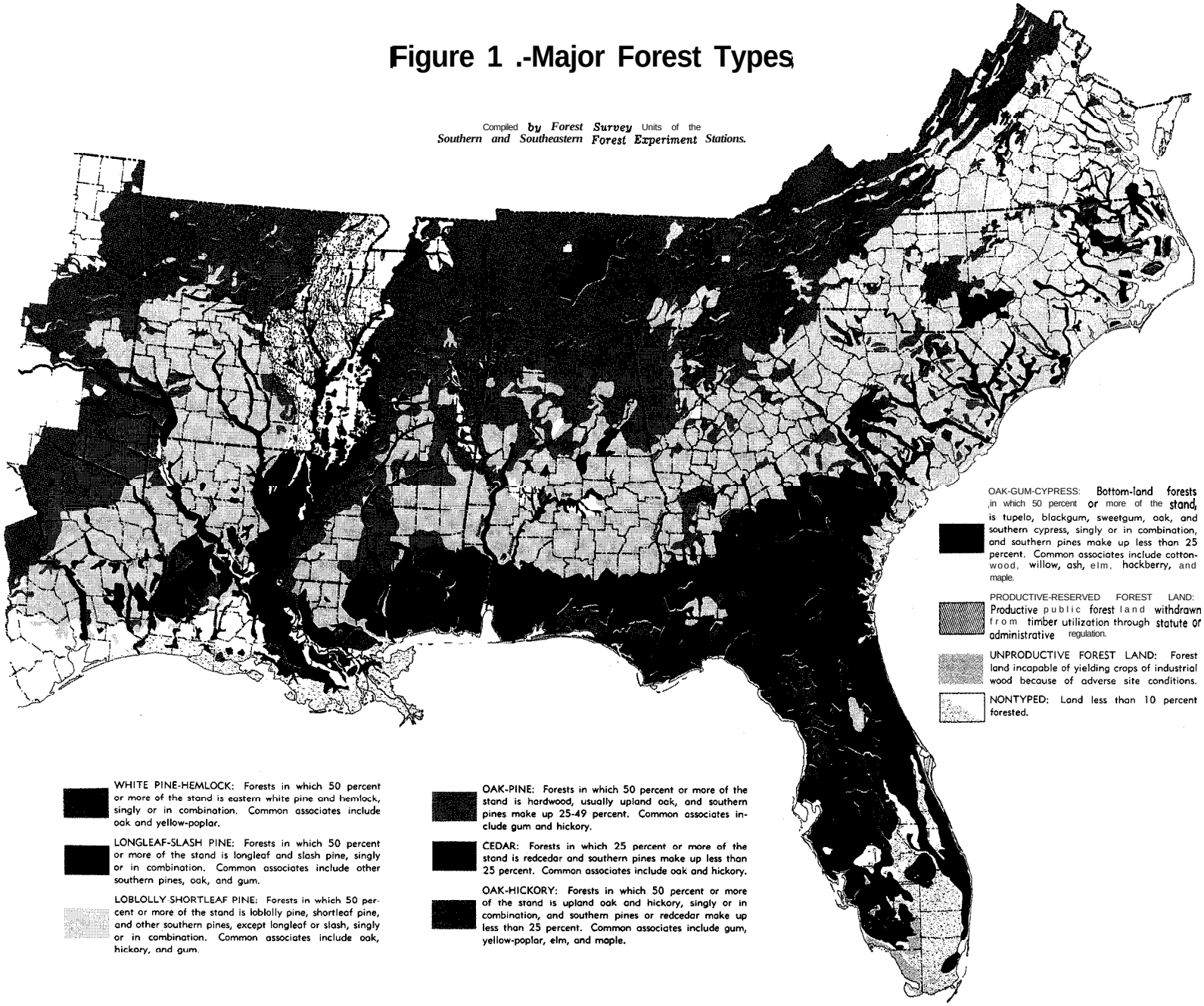
1. **OAK-GUM-CYPRESS**
2. **OAK-PINE**
3. **OAK-HICKORY**
4. **LOBLOLLY-SHORTLEAF PINE**
5. **LONGLEAF-SLASH PINE**
6. **CEDAR**
7. **WHITE PINE-HEMLOCK**

Pines are the most important commercial species. Most forest industries depend on pine, but there is a growing trend toward increasing use of hardwoods. The four major species of southern pine are loblolly, slash, shortleaf, and longleaf; all are classified as southern yellow pines. Eastern white pine is a white, soft pine of economic importance that is grown in the southern mountains as well as in the North. Baldcypress is another important conifer in the South, but it is restricted to bottomlands, ponds, or swamp areas of the Coastal Plain.

Oaks are the major commercial hardwood. Most important are white oak, southern red oak, and northern red oak. Yellow-poplar, sweetgum, blackgum, and water tupelo are important species used in furniture and veneer manufacturing. Sycamore and sweetgum are now being grown in plantations for energy wood and pulp. The harvesting of hardwoods for use in manufacturing pulp products is rapidly increasing, especially when the hardwoods can be mixed with pine pulp.

Figure 1 .-Major Forest Types

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



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.

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.

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.

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.

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.

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.

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.

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 Pests

In forestry, trees are considered to be the "crop. '' Forest pests, therefore, are things that compete with, injure, or spread disease to crop trees. The major forest pests fall into four groups: weeds, insects, diseases, and vertebrate animals.

Weeds

Weeds are any plants that interfere with land management objectives. They can compete with crop trees for limited moisture, nutrients, light, and growing space. Survival and growth of crop trees can be increased by effective control of weed competition, Other forest values, such as recreation and wildlife habitat, can be enhanced with proper vegetation management. That is why herbicides are the most commonly used pesticide in forests.

Insects

Forest trees are susceptible to insect attack at all stages of growth and development, from seeds to mature individuals. Although the majority of insect species are beneficial to a forest's health, some are exceedingly harmful.

Outbreaks of insects that damage forests economically vary greatly in frequency, size, and duration. Fortunately, most of these outbreaks are small, short-lived, and usually consist of one or a few spots in a stand or region. Others, however, may expand until they encompass hundreds or thousands of acres and may last for several years, as in the case of southern pine beetle outbreaks.

Most insecticide applications in forest management are primarily used in seed orchards and forest nurseries. Specialized applications are conducted periodically to control pine tipmoths, leaf cutting ants, gypsy moths, and southern pine beetles.

Diseases

Forest tree diseases include parasitic microorganisms, mainly fungi, bacteria, and plant rusts. Most microorganisms in the forest are beneficial and necessary for the functioning and health of the stand or ecosystem. Microorganisms are vital to nutrient cycling — they decompose leaves and branches, which results in the release of nutrients. Special fungi aid in nutrient uptake by tree roots, while most nitrogen for forest growth is supplied by bacteria living in the soil.

While most microorganisms are beneficial in forests, many are harmful to trees. Parasitic diseases can attack trees in all stages of their life cycles and cause poor health or even death. While some forest tree diseases attack many tree species, others target a particular species.

At this time, the only plant disease treated by chemical applications in southern forestry is annosus root rot.

Vertebrate Animals

Many kinds of animals can damage trees in the South. Their damage may vary from insignificant to very serious. Animal pests are deer, rabbits, squirrels, beavers, and other rodents. Animal damage to tree seedlings usually occurs when natural food sources are low and/or animal populations are high.

PRINCIPLES OF FOREST PEST MANAGEMENT

Integrated Pest Management

Using a combination of prevention and control methods is the best approach to pest problems. The planned strategy of combining the best methods is called **integrated pest management (IPM)**. Pest management should be a part of an overall management plan for a forest area and the need for pest control can usually be minimized through wise, long-term, forest practices. The control method(s) chosen will depend on 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 it will prevent the pest from causing more damage than is reasonable to accept. Even though a pest is present, it may not be necessary to control it. It could cost more to control the pest than would have been lost because of the pest's presence.

Pest Management Strategies

The three main pest management strategies are:

1. **Prevention** — Keeping a pest from becoming a problem.

2. **Suppression (Control)** — Reducing the pest numbers or damage to an acceptable level.

3. **Eradication** — Destroying or removing a pest completely from an area or geographic region.

Detection, through pest surveys, is an important activity with all three strategies. Often these three strategies are too costly so a fourth option — to live with the pest problem — is adopted.

Pest Control Methods

Many pest control methods have been known and used for years in agriculture, and are becoming more common in forestry. The most important are:

Legal Control — Legal controls result from Federal, State, or local laws and regulations. They include such things as quarantines, inspections, embargoes, and compulsory crop or product destruction.

Resistant Varieties — Trees grown from seed from certain areas or from selected individuals can be more resistant to certain diseases or be generally healthier on specific sites. Healthier seedlings do better at overcoming competition from weeds and resist disease, insect, and animal attacks. For example, tree breeding for resistance to fusiform rust is currently underway.

Biological Control — Biological control uses the natural parasites and predators of a pest to control its numbers. For imported pests, this means the careful introduction of parasites or predators from the home country into the new range of the pest in this country. Biological control can also be achieved by increasing the numbers of native parasites. For example, the control of the spread of gypsy moth is being attacked by spraying a bacterium or virus that specifically attacks the moth.

Cultural Control — Cultural practices that improve crop tree establishment and growth will often minimize pest influences. These practices include the use of only the best quality seeds and seedlings, proper seedling care before and during planting, planting patterns, timing of stand establishment, and fertilization. For example, outbreaks of pales weevil can be avoided by delaying replanting after harvest.

Mechanical or Physical Control — Mechanical treatments, such as chopping and shearing, are used for woody weed suppression. Traps are sometimes used for rats and voles.

Sanitation — Sanitation involves removing materials infected or infested by pests and the source of food on which pests feed, such as the fell-and-remove method for controlling the spread of southern pine beetles.

Prescribed Burning — Prescribed burning is often used to help control undesirable forest species and is often used in conjunction with other control measures. Some pine stands are prescribe burned on a regular basis to help control woody plant competition. It is an important part of most chemical site-preparation treatments. This practice reduces harvesting residues and thus improves planting access. In other weed-control efforts such as kudzu control treatments, prescribed fire is used to aid applicator access and to reduce vegetation that shields spray coverage. Prescribed burning also can help reduce brown-spot needle blight in young longleaf pine stands as well as annosus root rot.

Chemical Control (Pesticides) — Pesticides are chemicals used to control, eradicate, or prevent damage by pests. Pesticides are tested and labeled for specific pests, crops, and for specific land-use areas.

Steps to Solving Pest Problems

To solve pest problems, you should:

1. Correctly identify the pest(s).

2. Know what control methods are available.

3. Know and follow local, State, and Federal regulations that apply to the situation.

4. Evaluate the benefits and risks of each method or combination of methods.

5. Choose the methods that are effective yet will cause the least harm to you and the environment.

6. Correctly apply the treatment method and document the application and results through proper record keeping.

Pest control involves using all available methods to keep pest populations below harmful levels, while safeguarding the environment; and to recognize when direct action, such as a pesticide application, is necessary.

Forest Pesticides

Pesticides are used to regulate or disrupt plant growth; control, attract, or repel insect pests; prevent and control disease infections; and control, attract, and repel vertebrate animal pests. In southern forestry, herbicides are the most commonly-used pesticide. Insecticides are seldom used in general forest management because of high treatment costs and because some pest insects are highly mobile. The only disease-control treatment is employed for annosus root rot. Borax, applied to tree stumps, keeps the disease from getting established and spreading to the roots of nearby trees. Vertebrate animal control is often through trapping or hunting but may employ repellants and poison baits.

Forest Pesticide Registration

All pesticides used in the United States must be registered by the U.S. Environmental Protection Agency (EPA) as specified in the **Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)** and its amendments. Registration is either conditional or unconditional, based on data requirements set forth in FIFRA. Before a pesticide can be used operationally, data on the proposed uses must be evaluated by EPA. To develop a pesticide product and prepare it for registration under FIFRA, years of extensive scientific testing must be performed on the product's chemical properties, human and environmental safety, and efficacy (effectiveness). For forestry products, this may include testing under field conditions using commercial application equipment.

For wider testing of unregistered pesticides, EPA can issue an **Experimental Use Permit (EUP),** which establishes the limited conditions when an unregistered pesticide may be transported, applied, and disposed. Products subject to an EUP may only be sold or distributed to participants in the test program and only according to conditions described in the EUP.

Pesticides are registered by EPA as either general use or restricted use. A **general-use pesticide** is one that will not cause adverse effects to the environment when used for commonly recognized

practices in accordance with its label. Such pesticides are usually available to the public. **Restricted-use pesticides** require special procedures and training for applicators to prevent human exposure and environmental damage. EPA limits the purchase and use of **restricted-use** pesticides to certified applicators. Some products may be used only by certain categories of certified applicators. The label will state clearly who may use the product. States can also place general-use pesticides into the restricted-use category.

Another type of registration is commonly called the **Special Local Need (SLN)** registration. Under Section 24(c) of FIFRA, a State may register any Federally-registered pesticide for a pest not listed on the Federal label, provided that (1) registration for such use has not previously been denied or canceled by EPA, and (2) a food tolerance (safe levels in food), if required, has been established for the proposed use. A "special local need" exists when a State has an imminent pest problem for which an appropriate Federally-registered product is not sufficiently available. The State registration for these uses is deemed a Federal registration for purposes of FIFRA, but distribution and application of the product for these uses are confined to that State only.

There is a provision in FIFRA for providing assistance when unexpected pest problems arise. Section 18 of FIFRA permits EPA to exempt Federal or State agencies from FIFRA requirements when emergency conditions exist. This provision permits Federal and State agencies to respond quickly to emergency pest conditions in their jurisdictions with the use of pesticides not registered for the particular site and pest.

Classes of Pesticides

Pesticides can be grouped according to their chemical composition. The groups are:

- **Inorganic Pesticides** — These are made from minerals. Minerals used most often are boron, copper, sulfur, tin and zinc. Example: borate for prevention of annosus root rot infestations.

- **Synthetic Organic Pesticides** — These are synthesized pesticides that contain carbon, hydrogen, and other elements such as chlorine, phosphorus, and nitrogen. Most herbicides and insecticides in use are synthetic organic pesticides.

- **Plant-derived Organic Pesticides** — These are made from plants or plant parts. Examples: pyrethrins from chrysanthemums for insect control in forest nurseries.

- **Living Microorganisms** — These are viruses, bacteria, and fungi produced by culture. Examples: the bacterium, *Bacillus thuringiensis* (B. t.), and a virus, whose commercial formulation is registered as Gypchek, are being aerially applied as controls for the gypsy moth.

Pesticide Resistance

The ability of pests to resist poisoning is called pesticide resistance. The possibility of resistance must be considered when planning pest control programs that rely on the use of pesticides, especially large insect control programs. Rarely does any pesticide kill all target pests. Each time a pesticide is used, it selectively kills the most sensitive individuals. Some avoid the pesticide, while others withstand its effects. Pests that are not destroyed that are resistant to the pesticide may pass the trait that allowed them to survive to their offspring. At present, pesticide resistance is not an apparent problem in forestry applications, however, it may become one in the future.

VEGETATION CONTROL USING HERBICIDES

Weed Categories

Forest vegetation management is a term now being used to describe the planned approach to controlling weeds as part of a forest management plan. Weed species, or unwanted vegetation, can be classed as weed trees, brush, vines, and herbaceous weeds.

Weed Trees

Weed trees are hardwoods and conifers that interfere with management objectives or have other unwanted qualities. They include deformed, defective, or undersized individuals and trees of undesirable species.

Brush

This is a term for unwanted woody growth that includes shrubs and small trees. Brush prevents light from reaching crop tree seedlings and deprives seedlings and even taller commercial species of water and nutrients. Brush may interfere with commercial plantings and can create a habitat for rodents that may damage tree seedlings.

Vines

Vines are plants with climbing or creeping stems, including greenbriar, Japanese honeysuckle, wild grapes, and kudzu. All of these grow very well on many forest sites. They over-top trees, drag down branches and crowns, and compete for light and nutrients. Vines have vigorous sprouting habits and are some of the most difficult weeds to control.

Herbaceous Weeds

Herbaceous weeds are grasses and broadleaf forbs that retard seedling growth in new plantations and natural stands, mainly through competition for moisture. Seedlings may develop poorly or die, especially during drought conditions. Herbaceous weeds may also create favorable cover for tree-damaging animals. They also increase the potential for loss of a new plantation by wildfire. Herbaceous weed control is critical in forest nurseries, seed orchards, and Christmas tree plantings. Herbaceous weeds can be grouped according to how long they live — annual (1 year), biennial (2 years), and perennial (for more than 2 years).

Weed Control Treatments

Nearly all vegetation control in forests has been carried out in intensively managed pine forests and along forest rights-of-way. Under development and showing promise are single stem control methods as well. Herbicides can be used in forest management for a number of specific purposes.

Site Preparation

When preparing to plant seedlings, it is often necessary to reduce competing vegetation, reduce debris, and form beds in poorly drained areas. Mechanical methods for weed control, such as shearing and root raking, are expensive and often damage the site by displacing valuable topsoil and leaving the site vulnerable to erosion. By using herbicides for site preparation, applications are made in the growing season before planting for competition control, commonly followed by a prescribed burn for debris reduction to increase planter access. Herbicides may be applied using either aerial or ground application systems.

Herbaceous Weed Control

Research studies show that growth and sometimes survival of young pines and hardwoods can be increased by controlling herbaceous weeds, usually in the first growing season following planting. In addition, risk of fire can be decreased by an effective weed control program. Care must be exercised when controlling herbaceous weeds because tree seedlings can be damaged if label directions are not followed carefully. Soil erosion may also occur on susceptible soils with excessive control.

Crop Tree Release

When unwanted woody competition is not adequately controlled before planting, severe regrowth can overtop young pines or desirable hardwoods resulting in low crop tree survival or slowed growth. Selective herbicides or selective applications are used as release treatments to reduce brush (and herbaceous competition) without causing significant damage to crop trees. Directed sprays, basal sprays, soil spots, and injection treatments can also be used to control target woody stems while missing the crop.

Timber Stand Improvement (TSI)

In maturing stands, it is often profitable to eliminate low-value or cull trees that are competing with more valuable trees. Single-stem control methods may be used with injectors, spotguns, and sprays to the basal bark and cut stumps. TSI treatments with herbicides can also be used to prepare for regeneration of both pines and hardwoods in uneven-aged management. These methods can also be used to improve wildlife habitat by releasing mast and berry-producing trees and shrubs, as well as, creating openings that provide edge habitat.

Herbicide Application Terms

Special terms describe how and when to apply herbicides for use in forestry. They appear on labels and in leaflets and bulletins. Understanding these terms is very important to proper application.

Application Types

Terms that describe how to apply a pesticide include:

Broadcast — Uniform application to an entire area.

Band — 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 herbicide at a specific portion of a plant.

Foliar treatment — 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.

Spot treatment Application to a small area on the soil surface.

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

Stem injection — Application into incisions around a tree stem.

Application rate — The **application rate** is the specific amount of herbicide applied to a treated acre or target stem.

Application Timing

Herbicides work best if applied when the target plants are most susceptible or the crop trees are most resistant to injury. Applying them too early or too late reduces or even eliminates their effectiveness and may damage the crop. Terms that describe when to apply herbicides include:

Preplant — Applied before the crop trees are planted.

Preemergent — Applied before seedlings or weeds begin to grow (emerge) in the spring. In forestry, this term most often means applying the herbicide after the trees are planted, but before the weeds begin to grow, usually March to April.

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

Apply herbicides on woody plants only after all woody plants have fully resprouted after harvesting, burning, or mechanical treatments.

ApplicationMethods

Herbicides are introduced into unwanted vegetation in several ways. They may enter through the foliage, stem, or roots. Some can enter plants by more than one pathway. The application method for a herbicide is usually specified on the label. However, unless the label specifies that it is illegal to use a certain application method, any safe method may be used. The best method will depend on the situation, available equipment, and cost. Forestry herbicides are applied by aerial and ground methods. Ground methods will be covered in detail in the next section. Most States require a separate training and testing for aerial certification and so it Will only be discussed briefly here. Contact your State forestry agency for more specific information.

Aerial Application

Aerial application of herbicides is common in forestry because tract size is often large, access is difficult, and the target vegetation is tall and dense. Large acreage can be treated in less time and often more economically by air. Both liquid and dry formulations are aerially applied. Specially designed aerial spray equipment has been developed for herbicides that minimizes drift and achieves effective coverage. Droplet size of aerially-applied liquid herbicides is larger than that used for insecticides, although the effectiveness of foliar-absorbed herbicides may be reduced when large droplets are used.

Granular and pellet formulations of soil-active materials are also applied aerially. Although less subject to drift and weather conditions, uniform distribution can be difficult with these materials. Ground application methods can often supplement and complement aerial application where more strict control is required.

Mechanical Ground Application

Ground application by machine-mounted sprayers and spreaders offers several advantages compared to aerial methods. Machines can treat small areas or large ones, provide banded or broadcast applications, and are less limited by weather conditions. They are less visible than aircraft, so they are less apt to arouse undue public concern. However, due to terrain and stand conditions, ground machine applications have definite limitations and are slower.

Crawlers, skidders, 4-wheel drive farm tractors, and ATV's (all-terrain-vehicles) can be used for herbicide application. The machine used depends on the job to be done, site conditions, and equipment availability. The application equipment mounted on the machine must also be suitable for the selected herbicide and stand conditions. Broadcast-type sprayers must be able to cover a sizable area efficiently and uniformly while being very durable. For broadcast applications, boomless cluster-nozzles and off-center nozzles can be mounted up to 15 ft above the ground to reach tall brush and can cover a swath of 40 to 50 ft. The use of boomless nozzles has some limits. For example, tall brush may mask a major portion of the spray pattern. Also, the pattern of boomless nozzles is not uniform across the swath. Spray coverage of plants should be nearly complete, not just one-sided, for effective control. Various "manifold" type sprayers have also been designed for ground equipment as well as electrically-driven control droplet application (CDA) systems.

An alternative to broadcast foliar application is to broadcast soil-active, dry herbicides. These are granules or pellets that can be applied before full leaf growth masks the distribution. A specialized blower system can distribute these materials in a swath up to 80 ft wide. Fertilizer spreaders can be used to treat short vegetation.

Herbaceous weeds are often controlled in bands with farm tractors or ATV's using spray booms. One to three rows of seedlings can be sprayed per pass. The up-and-down sway of the booms should be minimized when treating two or more rows because the rate can change greatly as the boom ends change height.

Control systems are available for both sprayers and spreaders to ensure that herbicides are applied at a consistent rate under varying ground speeds. Maintaining the prescribed rate is critical for over-the-top release applications. With or without control systems, calibration of machine application equipment is necessary on a regular basis to assure accuracy of rate. Regular replacement of spray tips is also required for applying accurate and uniform rates.

Manual Ground Application

Manual applications are herbicide treatments that can be applied using backpack sprayers, spotguns, and injection devices. Manual methods are used to treat woody stems individually, apply granular herbicides for woody and herbaceous control, and to spray for herbaceous control in bands or spots.

GROUND APPLICATIONS OF FORESTRY HERBICIDES

Forestry applicators must be consistent to be effective, and those who work for a commercial applicator must be fast to be profitable. Consistency means mixing the correct herbicide accurately time after time. It means using well-maintained equipment with a steady effort.

Woody Plant Control with Sprayers, Spotguns, and Injectors

The commonly applied manual treatments for woody plant control are: (1) directed foliar sprays, (2) basal sprays, (3) soil spots, (4) tree injection, and (5) stump sprays. All sizes of trees and shrubs can be controlled by using the right treatment when the proper herbicide is applied at the correct time. Here are the sizes of woody plants that can be treated most effectively by hand methods:

Method	Effective size of target stems controlled
Directed foliar sprays	up to 6 ft tall
Full basal sprays	up to 6 inches d.b.h.*
Streamline basal sprays	up to 2 inches d.b.h.
Soil spots by grid	up to 10 inches d.b.h.
Basal soil spots	all sizes
Stump sprays	all sizes
Injection	sizes greater than 1 inch d.b.h.

*d.b.h. is diameter at breast height, which is the stem diameter measured at 4.5 ft above the ground.

Directed Foliar Sprays

Directed foliar sprays are best used to release l- and 2-year-old pine stands when brush competition is less than 6 ft tall. Caution must be taken to 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 too much pine is damaged.

Equipment — 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. Selection of a spray tip depends on the applicator's preference. Spray guns with narrow flat-fan tips are also used by some applicators.

Mixing — Accurate and thorough mixing is needed to assure consistent control. A wetting agent or penetrant can be added to the mixture to increase control of all herbicides, and is a label requirement for some herbicides. During windy conditions, a drift control additive can reduce drift that damages pines. Adding water-soluble dyes can help train new applicators and also guide experienced applicators.

Application Method — Apply the spray on the target foliage and be sure to cover the growing tips, but be careful to keep it off terminal shoots and leaves of crop trees.

Basal Sprays

Full Basal Full basal treatments require that the lower 12 to 20 inches of target hardwood stems be completely wetted on all sides with the spray mixture. See figure 2. A backpack sprayer is used with a wand or spray gun fitted with a narrow-angle flat fan, cone, or adjustable tip. Herbicides are used that are soluble in oil and mixed at percentages specified on labeled products, usually less than 10 percent. Some are sold ready to use.

Streamline Basal — Streamline basal treatments can control many woody plants including hardwoods up to 2 inches d.b.h. Trees of susceptible species up to 6 inches in diameter can be controlled. Treatment of small hardwoods less than 2 inches d.b.h. results in the most control.

To apply this treatment, a backpack sprayer is used with a spray gun and a low-flow (0.1-0.2 gallon per minute [gal/min]) straight-stream spray

tip. Also, a narrow-angle tip can be used, such as 15" and 0.1 gal/min. For controlling herbicide output to prevent waste, a pressure regulator is needed to maintain pressure below 30 pounds per square inch (lb/in^2). At these pressures, an effective reach of 9 ft is possible while bark splash is minimized. Sprayers with diaphragm pumps will maintain about 30 lb/in^2 with slow, steady pumping.

The most commonly used mixture for streamline application includes the herbicide (3 to 20 percent), a penetrant, and a carrier such as diesel fuel or mineral oil. This mixture is clear when made correctly, but a white cloudy liquid or jell will form if even a small amount of water is present. No amount of water should be in the sprayer or mixing container. Make sure that all water has been drained from the sprayer, the pump has been pumped dry, and the sprayer has been rinsed and pumped with diesel or mineral oil before filling with the mixture.

For treating stems that are less than 2 inches d.b.h., 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 at a point about 6 to 24 inches from the ground, to smooth juvenile bark. 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.

Applications are usually made 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. Applications should be avoided in young pine plantations on hot days if an ester formulation is used because pine injury may occur from vapor drift.

Soil Spot Applications

Spots of soil-active herbicide are applied to the soil surface in grid patterns or around target stems for site preparation and pine release. See figure 3.

In this method, exact amounts of herbicide, specified in milliliters (mL), are applied to the soil surface at prescribed spacings. Thus the effectiveness of the treatment depends on the applicator's accuracy and consistency in amount applied and spacing.

The rate for soil spot application is determined on the basis of whether the treatment is for site preparation or release, the texture of the soil, and the susceptibility of the target species. Because of possible pine damage, less herbicide is used for release treatments. Less herbicide is also used on

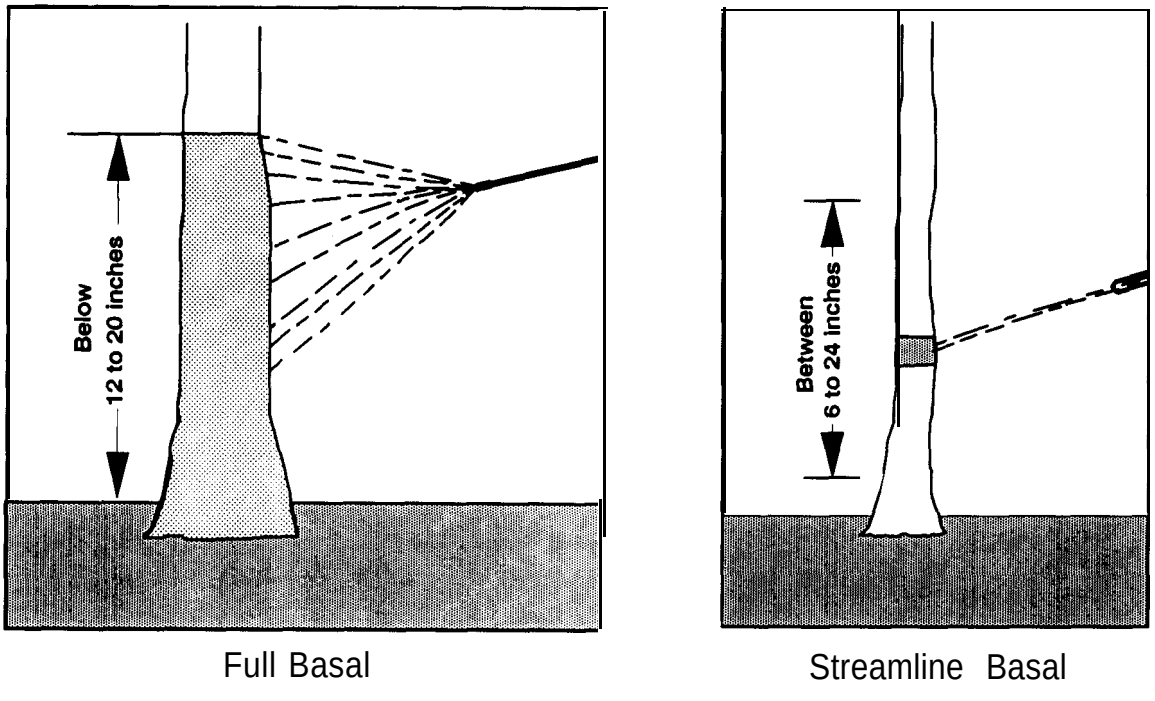


Figure 2.– Full basal method and streamline method of basal spray treatments for woody plant control.

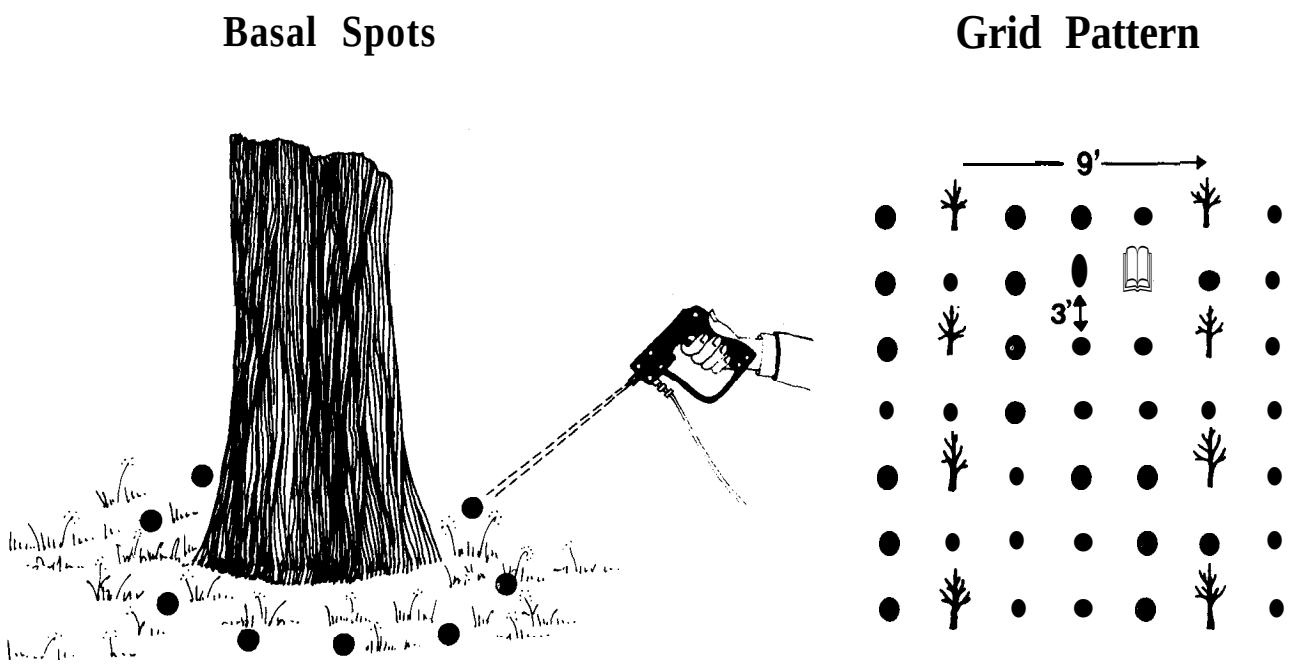


Figure 3.– Soil spot applications using basal spots and grid pattern.

sandy soils and more on clay soils. Seedling pines can be severely damaged or killed, especially when spots are placed too near.

Equipment — Spots are applied to the soil by using a spotgun 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. Both can be connected to a backpack sprayer to carry the herbicide, and the spotgun can also be connected to a backpack or side-pack container. A spotgun consists of an adjustable graduated cylinder or syringe that is operated by squeezing the handle. A forceful squeeze can project spots up to 1.5 ft. A spray gun uses pressure from the backpack sprayer to project spots to over 20 ft, thus requiring less exertion.

Spotguns are available in metal and plastic models. The more durable metal spotgun is for long-term use, while the plastic guns last for one area or one season. Water should be pumped through the spotgun after use, followed by a light oil for lubrication.

Calibration of spotgun — Spotguns are exact-delivery devices and thus either water or herbicide can be used for calibration. By turning the adjustment screw, set the piston of the syringe on the prescribed amount, for example, 2 mL. These graduations are not exact and must be checked. To do this, squeeze the handle 10 times and collect the solution in a container without splashing. Measure the amount using a container graduated in milliliters. For a 2-mL setting, it should deliver 20 mL after 10 squirts. If the total is more or less than the amount expected, adjust accordingly and repeat the procedure until the exact calibration is achieved. Any small error becomes large when thousands of spots are applied per acre and can result in wasted herbicide and poor control or pine damage. Calibration should be checked at least twice a day.

Spray gun for soil spot application — With practice, an applicator can use a spray gun equipped with a straight stream tip to apply 1- to 3-mL spots. The volume is determined by how long the handle is held in the pulled position and the size of the spray tip and pressure. A 0. 1-gal/min (gallons per minute) straight-stream tip is best for applying spots of about 1 mL; a 0.2-gal/min tip for spots of about 2 mL; and a 0.3-gal/min tip for spots of about 3 mL. Although the spray gun is not an exact delivery device, accurate dosages can be applied with practice and calibration.

Calibration of a spray gun and straight-stream tip — The backpack sprayer is pumped to the pressure that will be maintained during application, 20

to 30 lb/in^2. An appropriate tip is installed that matches the prescribed spot volume. For spots of uneven volume that are specified on the herbicide label, a tip should be selected that is closest to the prescribed volume. For example, a 0.2 gal/min tip can be used to apply a 2.3 mL spot and so on. The spray gun handle is pulled a few times while the clicking sound is noted, which helps to judge the rate of opening and closing of the handle. Using a container that prevents splashing, the volume from 10 pulls of the handle is collected. This volume is measured accurately using a container graduated in milliliters. The volume should be 10 times the desired volume per spot. For example, 10 pulls from a 0.2-gal/min tip, with a consistent rhythm of clicks, should give 20 mL. It takes practice to consistently apply the correct volume. Calibration should be checked at least twice a day.

Application Method — Spots are applied to the surface soil in grid patterns for treating areas or immediately around selected target stems.

Spot Grid Applications — Prescriptions for spot applications are usually specified by the volume per spot and the spacing between spots. If the prescription is given only in quarts per acre, then the volume per spot can be selected and the spacing calculated. For example, if the prescription specifies 6 quarts per acre and 2 mL spots are chosen, the number of spots per acre can be calculated by:

$$\text{Number of Spots/acre} = \frac{\text{Qt/acre} \times 946 \text{ ml/qt}}{\text{Number of ml/spot}}$$

$$= \frac{6 \times 946}{2} = 2{,}838 \text{ spots/acre}$$

Then to calculate the spacing between spots, the area per spot must be determined:

$$\text{Area/spot} = \frac{43{,}560 \text{ ft}^2\text{/acre}}{2{,}838 \text{ spots/acre}} = 15.3 \text{ ft}^2, \text{ or } 15 \text{ ft}^2$$

If the area around each spot is 15 ft^2, then a 3 ft by 5 ft spacing would work. Natural walking strides tend to match spacings of 3, 4, 5 and 6 ft, but strides must be determined before beginning application.

Generally, a close-grid pattern is used when the hardwood competition is small and a wider pattern is used when hardwoods are larger. Thus, close patterns are more commonly used for pine release and the wider spacing for site preparation. For example, to control mainly 6 to 8 inch d.b.h. trees, a wide grid is preferred, such as a 6 x 6 ft, 5 x 6 ft or 4 × 6 ft. To control thousands of small stems per acre, the most common pattern is 3 x 3 ft.

Single Stem Application — Apply 2 to 4 mL of undiluted herbicide for each 1 inch of d.b. h. The higher rate is needed for most situations other than sandy soils. Apply the spots on the soil within 3 ft of the root collar of the unwanted tree. When more than one spot is required per stem, the herbicide must be evenly spaced around the stem. All small stems of susceptible species that have roots in the treated area also will be killed.

Tree Injection

Tree injection is the least costly method for killing hardwoods that are greater than 1 inch d.b.h. This method can be used alone or in combination with other individual stem treatments for site preparation, pine and hardwood release, timber stand improvement, stand conversion, and creating cavity trees for nesting. This physically-demanding method requires workers who can repeatedly and precisely chop into tree trunks deep enough to properly deliver herbicide for uptake in the sap flow. Frequent sharpening and maintenance of injection tools is needed for best results.

Equipment — Common methods of tree injection use tubular tree injectors, hypo-hatchets, and the hack-and-squirt method. See figure 4. Tubular tree injectors consist of 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. To calibrate: fill and prime the injector; pull the handle or wire 10 times while collecting the herbicide in a container graduated in milliliters; if this is not 10 times the desired rate, adjust the lock-nut and repeat the procedure until accurate calibration is achieved. Frequent washings with water, including the pumping of water through the device, are the primary

Figure 4.– Tree injection using (A) tubular injector, (B) hypo-hatchet, and (C) the hack-and-squirt method.

maintenance procedure. Commercial applicators will want to carry spares for all rubber gaskets.

The hypo-hatchet consists of a hatchet with an internal herbicide delivery system that is connected by a hose to a herbicide container carried on the belt. When the hatchet strikes a tree, the blade must penetrate into the sapwood and the impact 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. Safety glasses should always be worn 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.

Hack-and-squirt is a method that uses a narrow-bit ax, hatchet, or machete along with a spray or squeeze bottle or oiler can. The hatchet, ax, and machete are used to cut into the sapwood, and the herbicide is squirted into the cut. A grinder can be used to narrow the bit of axes and hatchets for easier and better cuts. Most commercial spray bottles are set to deliver 1 mL with each trigger pull, but each one must be checked prior to use. Safety glasses should also be worn when using this method.

Waist-high injections by the hypo-hatchet and hack-and-squirt methods are just as effective and fast to perform as basal injections. With larger stems, more herbicide is applied by basal injections because of the larger groundline diameter compared to diameter at breast height.

Application Methods — The injection tool is used to cut into the sapwood around target trees at edge-to-edge spacings that are specified on the label. The sapwood must be penetrated, which is difficult on thick-bark species. Each cut must form a pocket in which the herbicide is placed for uptake. Usually 1 mL of herbicide is applied to each cut. The herbicide should stay in the pocket and not seep out through any split sides, because any herbicide on the bark is wasted. When treating sprouting clumps, each stem must be injected.

Stump Spraying

Stump resprouting of many species can be prevented by herbicide treatment. This can be an effec-

tive, low-cost treatment following harvest for site preparation and after partial cuts for timber stand improvement. Hand clearing treatments using saws or axes for pine release can be enhanced by treating the stumps with herbicide to prevent regrowth.

Equipment — A backpack sprayer is used that has a wand or spray gun equipped with a straight stream, fan, or hollow-cone nozzle. A sawyer can carry herbicide in a utility spray bottle for treating stumps after cutting. For small-diameter stumps, a wick applicator can be used.

Application — Freshly cut stumps should be treated as soon as possible after cutting. For stumps over 3 inches in diameter, the outer edge, or cambial area, must be completely wetted with the herbicide. Smaller stumps are usually completely wetted. To be successful, all small stumps should be treated. Thus it is best that the sawyer or companion applicator treat soon after felling so no stumps are skipped.

Older, cut stumps can be treated with the streamline mixture. The mixture is applied to the outer 1 inch edge of the stump until runoff and to the base of any sprouts.

Timing — Cutting and herbicide treatments can be performed during late winter and summer. Winter treatments are slightly less effective than growing-season treatments. Stump treatments within 4 hours of cutting have been shown effective — the sooner the better.

Woody and Herbaceous Control with Granule Applications

Hand-cranked broadcast spreaders can be used to 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.

Equipment

Granules and pellets are applied by hand-cranked spreaders, air-blown backpack spreaders, and hand-broadcast. Following are some basic facts about each:

Hand-cranked Broadcast Spreaders

- Spread an adjustable swath from 6 to 30 ft wide.
- Production rates up to 2 acres/hour.
- Weighs 4 lb unloaded and can carry 20 lb of herbicide.
- Models include sack-type, plastic bag, or metal and plastic hoppers.
- Spread is low and often blocked by trees and weeds.

Backpack Mist Blowers Modified to be Spreaders

- Increased individual productivity over hand-cranked spreaders.
- Treats a 30-ft-wide swath with fairly uniform distribution.
- Production rates up to 2.5 acres/hour.
- Weighs 20 to 25 lb and can carry 30 lb of pellets.
- High projection is possible for broadcast granules.

Hand-broadcast and Grid Applications

- Useful for very small areas and for directed or spot applications.
- Production rates up to 1 acre/hour.
- Backhand motions give a more even distribution than forehand applications.
- Large pellets are effectively applied in a grid pattern.
- Less productive than the other two methods.

- High projection is possible for broadcast granules.

The choice of method and equipment depends on the amount of land an applicator intends to treat, the terrain and stand conditions, and the anticipated effectiveness of each method. Of these three methods, hand-cranked broadcast spreaders present the best combination of cost and efficiency to most applicators and will be the focus here.

Hand Broadcast Spreaders

In general, hand-cranked spreaders are simple to operate and easy to maintain. In the spreading operation, pellets and granules fall by gravity through an adjustable gate opening onto a hand-cranked spinning disc that throws the material 20 to 30 ft. Much of the mechanisms are the same on many models, but several types of hoppers are available and each have certain advantages. See figure 5. Sack-type hoppers with zippers do not spill when accidentally tipped over on the ground or if the applicator falls. However, sack-type spreaders require two people for loading because the sides tend to collapse. Metal or plastic hoppers are the easiest to load, but spills can occur when the applicator trips or falls. Concentrated spills should be avoided. This can be done by using spreaders with a closed hopper. Also with any open hoppers, the applicator is exposed to fine dust particles.

Calibration — A calibrated spreader is needed to apply accurate rates. Calibrate the spreader by using the specific herbicide to be applied or by using blank granules and pellets when possible. Calibration will require accurate weight measurements in the field using a small spring balance. The calibration procedure is:

1. Adjust the gate opening (to a medium setting) so that the herbicide granules pass freely from the hopper onto the spinner disc.

2. Measure the width of the broadcast swath in feet. This can be done on a road or in a parking lot if blanks are used. Someone marks the outside edges of the swath while the operator cranks the spreader and moves forward.

3. Put a known quantity of the granular herbicide in the hopper (usually no more than 1 lb); make sure the herbicide is not clumped. Blank product (pellets and granules without herbicide) can be acquired from the manufacturer for this purpose.

4. Keeping a steady pace and constant cranking motion, apply the known amount of product in the treatment area. Walking speed must be the same as the actual application. Measure the forward distance in feet that are required to apply the known amount.

5. Calculate the pounds applied per acre.

$$\text{Rate} = \frac{43{,}560\ \text{ft}^2/\text{acre} \times \text{lbs of test product}}{\text{swath width (ft)} \times \text{distance traveled (ft)}}$$

For example, the test swath was 16 ft wide and the travel distance was 175 ft. One pound of product was applied while turning the crank at a constant rate. To determine the application rate:

$$\text{Rate} = \frac{43{,}560\ \text{ft}^2/\text{acre} \times 1\ \text{lb}}{16\ \text{ft} \times 175\ \text{ft}} = 15.6\ \text{lb/acre}$$

6. Adjust the gate opening if the prescribed rate is not achieved, and repeat the above procedure until the desired rate is set.

Application — Spring applications are recommended, when rainfall is usually sufficient to activate the herbicide and vegetation is actively growing. Applicators should become familiar with the site, its access and problem areas before making the application. Aerial photographs and topographic maps are particularly helpful for identifying sensitive areas such as streams and steep slopes. They can also help plan the locations for application transects and access to flagging stations.

Establish transects or treatment swaths so that they are equally spaced and parallel to each other. This is necessary to achieve uniform herbicide coverage. Flaggers are positioned at the ends of each transect to guide the applicator, who is busy keeping a proper pace and cranking speed. Transects can also be flagged before application, alternating the colors of flagging by transects.

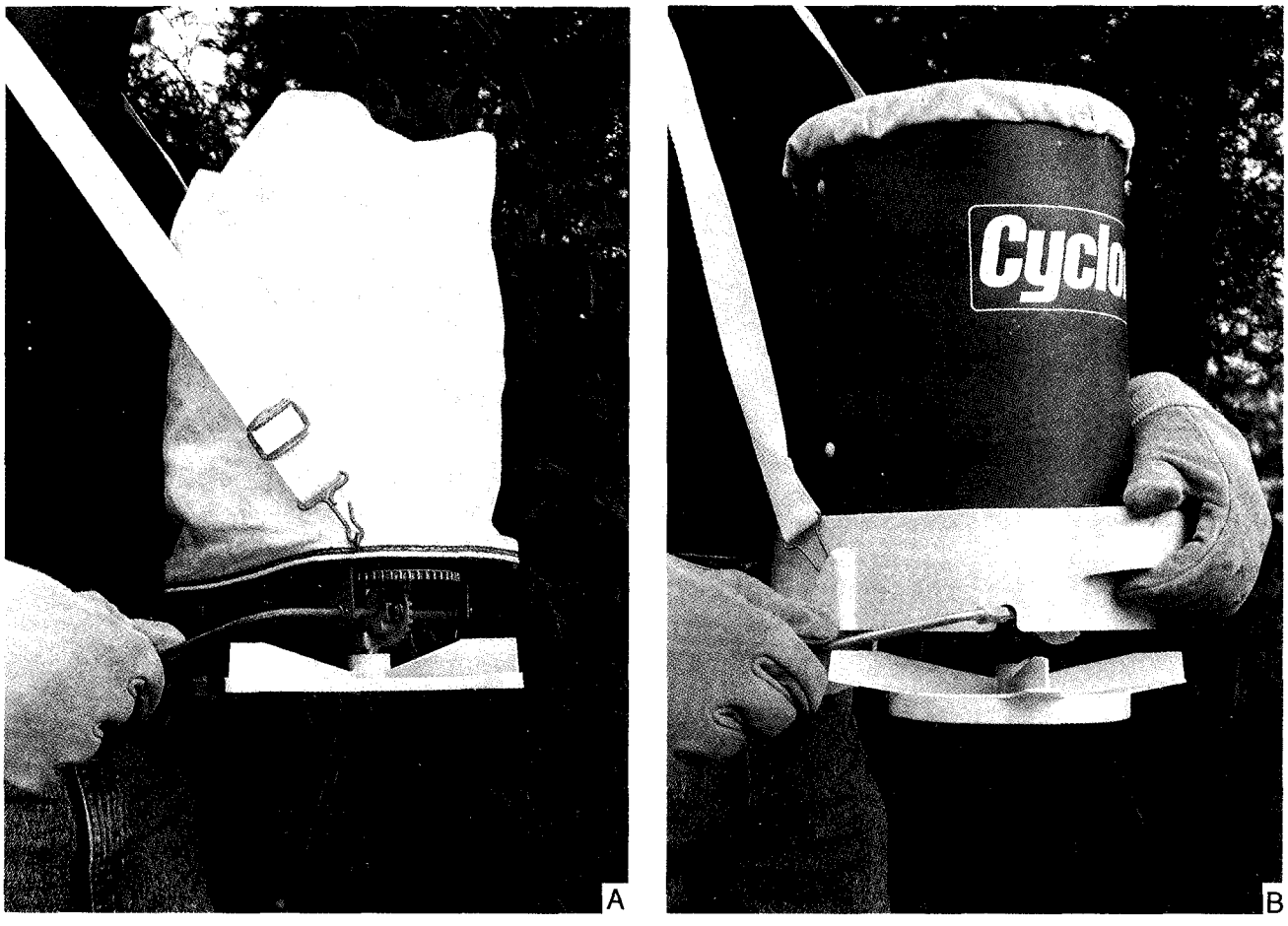


Figure 5.– (A) sack-type and (B) plastic hopper model of hand-cranked spreaders.

Herbaceous Weed Control in Young Pine Plantations

Research has shown that herbaceous weeds are often much stronger competitors to pine seedlings than are hardwoods. Herbaceous weed control can be accomplished using broadcast, band, or spot applications. Band applications are possible only when planting rows are well defined. Banded or spot applications cost considerably less than broadcast treatments and only small losses in growth and survival have been observed with banded or spot treatments relative to broadcast applications.

Banded Applications

Banded treatments are applied using backpack, ATV, or tractor sprayers. Backpack sprayers treat one row at a time while machine sprayers can treat two or more rows using a boom with spaced nozzles. Bands usually range from 3- to 6-ft wide.

To apply banded treatments, the boom or spray wand is fitted with a wide-angle flat-fan tip, such as 80" or 110°, with flow rates of about 0.2 to 0.3 gal/min. A special flat fan tip that is "even" will increase control on the band edges, compared to a regular flat fan that applies less herbicide on the edges. Also, flood tips, due to their wide angles, are commonly used for banded applications.

Pressure regulation and a constant nozzle height are needed to maintain uniform application rates. Use a pressure of 5 to 15 lb/in^2 to give large droplets with reduced drift. The low flow rates from low pressure operation also permit more acreage to be covered per fill-up, adding to the efficiency of the operation. Special "extended-range" or ''low-pressure" tips are designed especially for low-pressure applications. A pressure regulator is necessary to maintain low pressures with backpack sprayers. Some sprayers can be set at the desired pressure while others rely on the installation of regulators in line or on the wand.

Many types of sprayers can be modified to apply banded herbaceous weed control treatments in pine plantations. One increasingly common machine is a four-wheel ATV equipped with a sprayer. ATV sprayers can be equipped with sprayer control systems with ground-speed sensing. The sprayer control system maintains a constant application rate over a wide range of operating speeds. Protective clothing and equipment like that used in motorcross racing should be worn when operating an ATV sprayer in forestry conditions.

Calibration for Band Applications

Backpack Sprayers — The purpose of calibration is to determine the amount of solution that is applied per acre within the band. By knowing the amount of water sprayed per acre within the band, the rate of herbicide prescribed per acre can be added to that volume. Following is a calibration for backpack banded treatment:

1. Install the appropriate spray tip.

2. Fill the spray unit half-full with water and pump up the spray unit. Maintain the spray unit at constant pressure during calibration and application.

3. Hold the wand at a height that produces the desired band width.

4. Use the following table to determine the calibration distance required for the desired spray width.

Spray band width	Calibration distance
feet	
3	113
4	85
5	68

5. Measure the calibration distance on the ground within the area to be treated. Treat this distance at a walking speed you will use carrying a half-full sprayer and note the time.

6. For the amount of time noted from the above step, collect spray from the nozzle(s) and measure in a container graduated in ounces.

7. The ounces collected happens to be equal to the spray rate in gallons per acre.

8. If the total solution delivered per acre is not adequate, or too much, adjust the pressure or change tips and repeat steps 1 to 6.

9. Mix the desired rate of herbicide prescribed per acre with the gallons of solution delivered per acre.

EXAMPLE:

The measured spray width was 4 ft.

1. The calibration distance (see table) for a 4-ft band is 85 ft.

2. Walking the 85 ft with a half-full spray required 28 seconds.

3. The nozzle sprayed 14 ounces in 28 seconds; therefore, the sprayer is applying 14 gallons per acre within the 4-ft band.

Machines — To calibrate a machine sprayer one needs to know the same information including speed, band width, and sprayer output. A step-by-step procedure for machine calibration is as follows:

1. Adjust the boom height to give the proper band width and adjust the pressure. This height and pressure should be maintained during calibration and application.

2. Using a throttle and gear setting that will be maintained during application, measure in feet the distance travelled in 1 minute. This should be done on terrain similar to the treatment area.

3. Collect the spray volume from all nozzles for 1 minute and accurately measure this volume to

the nearest tenth of a gallon (fluid ounces × 0.0078 = gallons).

4. To calculate the portion of an acre treated in 1 minute, multiply the band width or sum of multiple-row band widths (measured in feet) by the distance travelled in 1 minute. Divide by 43,560 square ft per acre. For example, one 3-ft band is sprayed at 145 ft per minute:

$$\text{Portion of an acre treated in 1 minute} = \frac{3 \times 145}{43{,}560} = 0.01 \text{ acre}$$

As another example, two 3-ft bands are being treated by a boom sprayer at 145 ft per minute. Thus, 6 ft of band width would be used in the calculation and 0.02 acre was treated per minute.

5. To calculate the amount sprayed in the band, per acre, divide the gallons sprayed in 1 minute by the portion of an acre treated in 1 minute. For example, 0.2 gal/min is collected and 0.01 acre was treated:

$$\text{Gallons per acre} = \frac{0.2 \text{ gal/min}}{0.01 \text{ acre}} = 20 \text{ gal per acre}$$

This is the amount of spray solution being applied to an acre within the bands.

6. Mix the per-acre rate of herbicide in proportion to the gallons per acre of spray solution. For example, if 3 oz of herbicide is the prescribed rate per acre, then 3 oz of herbicide is added to every 20 gallons of water in the mixing tank. To mix 200 gallons of spray solution, divide the total gallons by the gallons per acre and multiply by the rate. Use these calcuations:

$$\text{Amount of herbicide to add to a tank} = \frac{\text{total gallons}}{\text{gal per acre}} \times \text{rate}$$

$$= \frac{200 \text{ gal}}{20 \text{ gal per acre}} \times 3 \text{ oz} = 30 \text{ oz}$$

Thus, add 30 oz of herbicide to 200 gallons of water, to treat 10 acres at a rate of 3 oz per acre. Check the calibration when you start a new area, use a new rate, or when equipment has been repaired or altered. With proper calibration of the equipment, banded applications can begin.

Spot Applications for Herbaceous Weed Control

Spot applications must be used when planting rows are not well defined. Spot applications can be made using the above banding procedure with some change. Mainly, the sprayer is turned off between seedlings as the applicator follows the rows. The sprayer is turned on about 1.5 to 2.5 ft before the seedling and shut off at the same distance past the seedling. Thus the same tips, pressure, and calibration can be used. The applicator must still maintain a constant walking speed while spraying each seedling if the rate is to be constant.

Full cone tips, with flow rates from 0.2 to 0.4 gal/min, can be used to apply circular, tree-centered spots using a backpack sprayer or spotgun. However, full cone tips with these low flow rates produce very fine droplets that are easily blown by wind. An adjustable cone nozzle produces large droplets, but these droplets are too large to ensure uniform coverage of preemergent herbicides.

CHEMICAL INSECT AND DISEASE CONTROL

Forest trees are susceptible to insect and disease attack at all stages of growth and development. Maintaining healthy and vigorous stands and individuals can lower the risk and incidence of insect attack. However, uncontrollable soil, site, andweather conditions preclude the elimination of diseases and insects as a threat to forest trees. Only a few forest insects and only one forest disease are treated chemically in the field for prevention or control.

Refer to the pesticide handbook of your State (if available) or consult a local extension specialist for a list of currently registered pesticides approved for the following pests.

Pine Bark Beetles

Southern Pine Beetle

The southern pine beetle (SPB) (*Dendroctonus frontalis*) is the most destructive forest insect in the South. Weakening of trees by lightning, drought, flooding, or windstorms may predispose otherwise resistant or healthy trees to attack by SPB. Widespread subregional outbreaks occur every 5 to 10 years and last 1 to several years.

The SPB is a small, reddish-brown-to-black beetle about 1/8 inch long. The rear of the body is rounded in contrast to the scooped-out posterior of Ips beetles. The first indication of attack is usually the yellowing or browning of needles. Small pitch tubes (white, yellow, or reddish brown) about as large as a small piece of popped popcorn (or a wad of gum) are sometimes present on the trunk, starting at a point about 3 feet from the bottom of the trunk and continuing up into the lower one-third of the crown. Under droughty conditions, pitch tubes may be very small or even absent and only reddish-brown, boring dust will be present.

Adult beetles bore directly through the bark and mate there. The females excavate S-shaped egg galleries in the inner bark, which can be observed by peeling off the outer bark. These galleries are different from the Y- and H-shaped galleries of Ips beetles. White eggs are deposited in niches on either side of these galleries and hatch into small, legless larvae in 4 to 9 days. The larvae mine for a short distance before boring into the outer bark where they pupate. The larvae are about l&inch long, white, and have reddish-brown heads. The pupae are pure white and about 1/8-inch long.

There are 3 to 7 generations per year, depending on locality and weather. Soon after a tree is attacked, all the needles usually turn yellow and then brown.

In addition to causing direct damage, SPB's introduce blue-stain fungi, which may clog the water-conducting tissues. Death may be hastened when blue-stain fungi are introduced. The stain decreases the value of the tree.

There are several alternatives to chemically controlling SPB infestations that can be used in appropriate circumstances. These include cut-and-leave, pile-and-bum, andcut-and-remove. Cut-and-remove, the preferred method, and pile-and-burn can be used year-round; cut-and-leave should only be used during the summer. All require that a buffer strip of green, uninfested trees be cut at the head of an active SPB spot; professional help is recommended to best implement any of these methods.

Ips Beetles

Ips beetles (*Ips grandicollis, I. calligraphus, I. avulsus*, and *I. pini*) usually attack trees weakened by natural or man-made causes, and often follow SPB's. They usually attack and kill only one or a few trees in a given spot, but if conditions are satisfactory, they may become edpidemic and destroy hundreds of trees. Adults girdle trees quickly as they construct their egg galleries in the inner bark. Death is usually hastened by the introduction of blue-stain fungi, which block the flow of sap and degrade the wood.

Ips beetles are yellowish, dark reddish-brown, or black. They are 1/8- to 1/4-inch long. They are easily recognized by the scooped indention of their posterior end which is surrounded by tooth-like projections. Pitch tubes on bark or branches, or the presence of boring dust, often indicate Ips attack. If the tree is healthy, attack by Ips may not be successful even though pitch tubes are present.

Fully grown larvae and pupae are yellowish-white and range from 1/8 to 1/4 inch long. Gallery patterns are more or less Y- or H-shaped. The eggs

are small andwhite. Eggs are laid in small egg niches cut along the main tunnels. Upon hatching, larvae feed, forming fine tunnels perpendicular to the egg niche. Later feeding results in meandering tunnels, usually filled with boring dust and frass. In hot weather, it takes only 18 to 25 days to complete one generation. Four or five generations occur each year.

Black Turpentine Beetle

Generally not considered a major forest pest, the black turpentine beetle (BTB) (*Dendroctonus terebrans*) can kill apparently healthy trees in a stand. Attacks are increased by natural and man-caused stress, such as drought and logging damage to trees and soil.

The BTB is the largest of the major southern bark beetles. It is 1/4 inch or more in length and the rear end is rounded. The color is reddish-brown to black. Large pitch tubes (up to walnut size) are caused by this insect. BTB's attack the lower trunks of living pines (from the base to 15 feet up, but generally in the lower 8 feet). The beetle attacks fresh stumps and living trees by boring through the bark and constructing galleries on the face of the sapwood where eggs are laid. Fifty to 200 eggs are laid in a group. They hatch into white larvae, which feed on the inner bark.

BTB's may girdle and kill trees when several broods occur at about the same height. Generally, 10 to 25 percent of the infested trees die. The entire life cycle takes 2-1/2 to 4 months, depending on temperature. Each year in the South there are usually two full generations and part of a third.

Bark Beetle Chemical Control

Many trees newly attacked by BTB can be saved by spraying from the base up to the highest pitch tube on the trunk with an approved insecticide.

If insecticides are used to control an active SPB infestation, the following procedures are recommended. Fell all infested trees. Do not fell a buffer strip of uninfested trees or vacated trees. Limb and cut the felled trees into workable lengths. Using a low-pressure sprayer, treat the entire bark surface with an approved insecticide, turning the logs as necessary.

Pine Tip Moth

The Nantucket pine tip moth (*Rhyacioniu frustrana*) is common in the South. Its importance in pine plantations and nurseries varies widely with tree species, tree vigor, and environmental factors. Heavily infested trees may be severely stunted or deformed but are rarely killed. Generally, the tree grows out of the susceptible stage within a few years. All species of pines are attacked except white and longleaf.

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; mature larvae are light brown and about 3/8-inch long. Pupation occurs in the damaged pine terminal.

Adults begin to emerge on warm days in late winter or early spring and begin laying eggs within a few days. Eggs are deposited on needles, stems, developing tips, or buds. The larval period lasts 2 to 4 weeks. Several generations occur each year.

Tipmoth Chemical Control

Insecticide spraying for tipmoth is not generally practiced, except in special cases such as progeny tests, Christmas tree plantations, research study plots, and some intensively managed pine plantations. Insecticide application must coincide with moth emergence, which varies by location. Trapping insects can identify the times of emergence, and spraying treatments planned accordingly.

Pine Sawflies

The redheaded pine sawfly (*Neodiprion Zecontei*), blackheaded pine sawfly (N. *excitans*), and loblolly pine sawfly (*N. taedae linear-is*) attack most species of southern pines. All have caterpillar-like larvae that feed on pine needles and can defoliate seedlings and saplings. Usually they attacksingle trees or small groups of trees; however, if conditions are favorable, they may infest and defoliate thousands of acres of naturally regenerated or planted pine. Repeated attacks on the same trees for 2 or more years may kill them, but the main loss is in tree growth. Sawflies are not economically important

pests of most forest stands, except in Florida where insecticide treatment is necessary.

Pine Sawfly Chemical Control

Treatment is usually by aerial applicator for large plantations or ground equipment for smaller ones.

Texas Leaf-cutting Ant

Texas leafcutting ants *(Attu texana)*, also known as town ants, are destructive reproduction pests in Texas and Louisiana. This ant can completely defoliate and girdle a small tree overnight. Such defoliation can be fatal to young pines. The ants strip the needles and leaves from both pines and hardwoods and use this plant material to culture a fungus that is their only known food. Damage is most severe to pines in the winter when there are no other green plants. Pine reproduction can seldom become established where ants are present because they destroy newly germinated or planted seedlings.

Texas leafcutting ants are rust-brown to dark brown and differ greatly in size. Workers range from 1/16 to 1/2-inch long and have three pairs of prominent spines on the thorax. From April to June winged males and females leave the colony on mating flights and subsequently establish new nests. An ant nest area, or "town," is marked by many cone-shaped mounds, usually 5 to 14 inches high and about 1 foot in diameter. The town may cover an area from several square feet to nearly 1 acre.

Texas Leaf-cutting Ant Chemical Control

Find and treat all nests in or near areas to be planted. Scouting is easiest during fall and early winter when the ants are active and their mounds are not hidden by vegetation. A formulation of the fire ant bait Amdro is registered for leaf-cutting ant control. Fresh bait from a newly opened container should be used for most effective control. Colonies can also be eliminated by fumigating with methyl bromide or carbon bisulfide. However, fumigating should not be done near human dwellings.

Pine Reproduction Weevils

The pales weevil *(Hylobius pales)* and the pitch-eating weevil *(Pachylobius picivorus)* are very destructive of first-year pine plantations growing on recently cut-over sites. Weevils eat patches of bark from the stem of a seedling and when these feeding areas overlap, the seedling is girdled and dies. Both weevils will feed and develop on all species of pine within their range. Adults are oblong, black to reddish-brown, less than 1/2 inch long. Winter is spent as an adult or mature larvae in a chip cocoon constructed under the bark of a pine stump. In spring, adults emerge and feed on the bark of saplings and at the bases of seedlings.

The weevils feed at night and hide under debris at the bases of seedlings during the day. If the insects are abundant, they may remove all the bark and foliage, leaving only yellowish, pencil-like stubs. Most damage occurs in spring and fall. The adults are attracted to the odor of freshly cut pine stumps, scorched pines, or dying trees and feed on the tender bark of nearby seedlings. When these high-hazard conditions (fresh stumps, scorched stems, etc.) occur, weevils may kill 90 percent or more of the pine seedling in the reproduction areas; 30-60 percent pine seedling mortality is not uncommon.

The most practical method of control is to delay planting recently harvested areas for 9 to 12 months.

Pine Reproduction Weevil Chemical Control

Infestations of pine reproduction weevils can be prevented by dipping seedling roots in an insecticide/kaolin clay mixture, top dipping seedlings, or over-the-top insecticide spraying.

Gypsy Moth

When it is present, the gypsy moth *(Lymantria dispar)* is one of the most damaging forest pests. Females do not fly. This peculiarity probably accounts for the insect's slow spread from established infestations into new areas. (Note: In 1993 an Asian strain of this moth was introduced in several loca-

tions on the eastern seaboard of the United States. The females of this strain do fly and are expected to severely impair future control efforts. However, how bad the problem will be is not yet known. So, the remainder of this discussion is limited to the European strain of gypsy moth currently found in the East.

The moths are harmless, but the caterpillars feed on the leaves of forest, shade, ornamental, and fruit trees as well as shrubs. A single defoliation can kill some softwoods, two or more defoliations can kill many hardwoods. Large infestations involve millions of caterpillars and can degrade esthetic and recreational values of forests, parks, and wooded homesites.Few trees are killed outright by gypsy moth defoliation, but many trees are weakened and become susceptible to secondary attack by other insects or plant diseases. During the last 80 years, parasites of this pest have been introduced into infested areas. However, control of the gypsy moth by its natural enemies has been less effective than hoped.

Gypsy Moth Chemical Control

Aerial spraying with the insecticide dimlin has been done in several southern States to control gypsy moths and may be required in other States as the moth migrates southward. The bacterium ***Bacillus thuringiensis*** (B.t.) and a virus (Gypchek) are being aerially applied to control gypsy moths.

Annosus Root Rot

In the South the only tree disease chemically treated on an operational basis in the forest is annosus root rot. It infects many pines and other conifers. Infected trees grow slower and are more susceptible to bark beetle attack than healthy trees. Infected trees are also susceptible to spontaneous root failure and windthrow. The root rot is caused by ***Heterobasidion annosum,*** a fungus that grows in the duff at the base of potential host trees. An example is shown on the front cover, bottom inset photo. This fungus causes a white, stringy, rot of the roots and occasionally the butts of living trees. Eventually, the entire root system may be destroyed. The fungus spreads by airborne spores that germinate on freshly cut stump surfaces. Infections in plantations can usually be traced to root contacts or grafts between healthy and infected trees.

Infected trees have thin, light-green to yellow crowns and short needles, tufted at the branch end. Conks (the shelf-like fruiting structure of the fungus) are not produced on most trees and are often difficult to locate when they do appear unless the duff layer is removed.

Trees tend to die in pockets, with trees in the center dying first. In thinned pine plantations, high-hazard sites can be 80+ percent infected. High-hazard sites are well drained soils with at least 65 percent sand in the upper 12 inches of soil and a low water table.

Annosus Root Rot Chemical Protection

Sodium tetraborate (borax) is the most effective protection against stump surface colonization, residual tree infection, and mortality. Just sprinkle borax or Borateen on a stump with a salt shaker or any other shaker-type container. Sodium tetraborate will not prevent transmission of ***H. annosum*** through root systems in already infected stands. Such stands should be treated with ***Phlebia gigantea,*** a fungus that competes naturally with ***H. unnosum.*** Thin the infected trees in the summer.

FOREST SEED ORCHARDS AND NURSERIES

Seed Orchards

About 10,000 acres of forest tree seed orchards in the South are intensively managed to produce the seed required for artificial regeneration programs. While these seed orchards represent a very small area, their impact upon forest production in the South is very large. In 1987, these seed orchards produced enough seed to grow 1.3 billion seedlings that were used to reforest 1.8 million acres of land. This represented 85 percent of all reforestation efforts in the South. A conservative estimate of genetic gain for these seedlings is a lo-percent increase in volume growth, which has a value of $43.5 million (1990 figures). Additional value will be created by improvements in form and disease resistance.

Intensive management is critical to obtain the required amount of seed from these orchards. Cone- and seed-insect control programs are an integral component of a seed orchard management program because these insects can easily destroy more than 50 percent of the potential seed crop. In some cases, losses to cone and seed insects have exceeded 90 percent of the potential seed crop. Additional control techniques, both biological and chemical, are needed to ensure a continuing supply of genetically-improved seed for future reforestation efforts.

Chemical control is achieved by ground and aerial application methods. Hydraulic sprayers, airblast sprayers (mistblowers), and handheld compressed-air sprayers are all used to control different species of seed- and cone-insect pests. Aerial application is increasing. Both helicopters and fixed-wing aircraft are used to apply insecticides with either conventional or ultra-low volume equipment. The use of aircraft has resulted in much less exposure to workers at seed orchards and reduced losses due to insect damage.

Insecticides used in seed orchards range from very toxic (azinphosmethyl) to very non-toxic (synthetic pyrethrins) to man and animals. Research for safer insecticides is continuing.

Forest Nurseries

Forest tree nurseries are intensively-managed sites that use considerable amounts of pesticides. Nurseries in the South grow about 80 percent of all the bareroot stock produced in the United States. Loblolly and slash pine account for about 90 percent of this production, although in recent years there has been increasing interest in longleaf and sand pine, as well as hardwoods. Most of the pesticide technology now used in forest nurseries was developed for pine seedling cultivation.

Fumigants, herbicides, fungicides, and insecticides are used routinely to control a number of major pests of tree seedlings. A number of pesticides have labels specific to tree-seedling nurseries. The Environmental Protection Agency also allows the use of pesticides labeled for horticultural nurseries to be applied in forest-tree nurseries. Individual States, however, may find exception to this general policy.

Fumigants are used in nurseries to control pathogens and weeds. Weed control alone, however, does not sufficiently justify fumigation as there are cost-effective herbicides specifically labeled for use with pine seedlings. On the other hand, pathogens can be a serious problem so protection from various damping-off fungi and other soilborne organisms is considered a wise investment. Proper soil conditions are essential for effective fumigation.

Herbicides used in nurseries have been developed mainly for pine production. A number of effective compounds are labeled to control grasses and broadleaf weeds in pine seedbeds. Herbicides are usually applied over-the-top of the beds when weeds first appear. Applications are repeated throughout the growing season as deemed necessary. Weed control in hardwood nurseries is more difficult. Not only are fewer compounds labeled for weed control in hardwoods, but herbicides are specific for hardwood species. If not properly matched, serious seedling damage can result. Herbicides are also used for broad-spectrum weed control by spot treatment around irrigation lines, roads, and buildings.

Fungicides are most often used in forest nurseries to prevent and control fusiform rust. Fungicides may also control damping-off during and immediately after seed germination. Several stem and foliar diseases also periodically require use of fungicides. Under nursery conditions of dense seedbeds, high fertilization, and irrigation, disease problems must be found and addressed quickly.

Insecticides are commonly used in nurseries. Some of the more common insect pests are lesser cornstalk borers, spider mites, aphids, lygus bugs, and white grubs. A number of insecticides are labeled for insect control in forest nurseries, although the chemical must be matched with the pest for maximum effectiveness.

VERTEBRATE ANIMAL CONTROL

Many kinds of animals can damage live trees in the South. Their damage may vary from insignificant to very serious. The mammalian pests — deer, rabbits, squirrels, and other rodents — present the most serious problems. With an animal-damage situation, always check State and local regulations. Due to their potential for greater economic impact, beaver and deer will be discussed separately. Other species may cause damage locally, but are not a widespread or severe threat to trees.

Beaver

Beavers are capable of greatly altering their habitat to suit their needs. As they girdle and fell trees to build a lodge and dam, standing timber often becomes flooded and eventually dies. From a wildlife management standpoint, beaver ponds are very beneficial; from a timber producer's standpoint, beaver ponds may be costly.

Due to the sizeable beaver population in the South, live-trapping and relocating offending animals is no longer a realistic control alternative. There are no repellents, toxicants, or fumigants registered for beaver control. Eliminating beaver from an area requires a combination of trapping or shooting, and destroying their dams. One of the most effective traps for beaver is the 330 Conibear. This trap, when properly set, kills the beaver instantly. When all the beavers have been trapped from a pond, the dam can be destroyed and the water drained from the flooded timber.

Deer

Deer, like beavers, have expanded in the South. High populations, coupled with voracious feeding habits, can badly damage newly established forests. Deer prefer to browse on the leaves, stems and buds of woody plants. They will browse on both pine and hardwood seedlings. Browsing damage by deer is easy to identify by the presence of the distinctive deer tracks and the characteristic pattern of nipping the plant. Deer have no upper front teeth, so they must tear off pieces of the plant, leaving a jagged end. Bucks may also rub small pines with their antlers during the rutting season. Damage caused by antler rubbing appears as an area where bark has been scraped off the tree trunk. Generally, rubbing damage to young pines (up to 4 inches in diameter) by rutting bucks does not present an economic threat except in high-value plantings such as seed orchards and Christmas trees.

Deer are protected as game animals throughout the region, but in cases of severe damage, it may be possible to obtain a permit to shoot depredating deer. Various scaring devices may be effective for short periods, but deer soon become acclimated to them. Repellents are short-lived and expensive. In areas with many deer, seedlings can be treated with a repellant and planted late in the season to extend the effect. The most effective control measure may be exclusion of deer from the area. This can be accomplished by 8-foot high woven-wire fencing or various configurations of electric fencing. Sport hunting in the area may help control population expansion.

Small Rodents

Cotton rats may feed on the roots, stems, and leaves of seedlings. Cotton rats prefer dense cover; therefore, keeping the area around the young trees clean through herbaceous weed control will help to reduce cotton rat problems. In small areas, cotton rats may be excluded by using sheet metal fencing; the bottom of the fence should be buried 6 inches in the ground. Repellents, toxicants, and fumigants are not effective in large-scale operations. The damage caused by this species is generally local.

Voles, small mouse-like animals with short tails, may damage seedlings by girdling. They usually have extensive systems of burrows and runways in the ground litter. Trapping is not effective in large-scale operations; however, some success may be achieved with repellents and toxicants such as zinc phosphide. Check local regulations before using any chemical control measures. Voles rely on vegetative ground litter for cover, so keep the area around young trees clear of vegetation to help reduce vole damage.

Pocket gophers are burrowing animals that eat parts or entire root systems and expose roots so that they dry out. Gophers can often be detected by the presence of surface mounds. They are not usually a pest in forest situations. However, damage can be quite significant where pastures and old fields having sandy soils are machine planted to pine. Pocket gophers can be controlled using baits containing zinc phosphide .

Rabbits may damage young trees by girdling or clipping off branches. Their damage may be distinguished from deer browsing by the smooth-angled cut left at the end of the branch. Rabbit droppings can usually be found in the damaged area. Like deer, rabbits are game animals that are protected by State regulations, but some States do allow exceptions in damage cases. Exclusion and trapping are generally not effective for large-scale operations. Some repellents containing thiram have proven effective in discouraging rabbit browsing and gnawing. Eliminating brush piles and other cover may be useful in reducing high rabbit populations. Biological control of rabbits, by encouraging the presence of natural predators (hawks, owls, and snakes) may help lower populations. Sport hunting on an area can aid in population control.

Other Animal Pests

Fox squirrels may damage pines in the South by eating cones, and by chewing pine bark. Fox squirrels are game animals and are covered by seasons and other regulations. In isolated cases, squirrels may be prevented from climbing individual trees by installing a 2-foot-wide sheet of metal around the trunk. For large-scale forestry operations, toxicants and repellents are usually not effective. Trapping or shooting can generally be used to eliminate offending animals, but during peak years, new squirrels may soon move into the area to replace those that were eliminated.

Feral hogs are descendants of free-ranging domestic hogs or those released for sport hunting. Feral hogs may damage young stands of timber by rooting around the bases of trees. Large-scale fencing to exclude hogs is generally not practical, and there are no toxicants registered for hogs. Live-trapping and removal during the spring and summer when acorns are scarce, and hunting during the fall and winter may be effective in controlling feral hog populations.

RECORD KEEPING OF PESTICIDE TREATMENTS

Keeping records of pesticide usage is required by law. By Federal regulations, records for each application of "restricted use" pesticides must be kept on file for at least 2 years. Records can establish proof of proper use in damage suits, and they are helpful in finding the cause of error if an error was made. They can also provide information to trace residue and damage problems. Such records can also be helpful in liability cases.

Records can also help save money. They allow comparison of results obtained from different pesticides, which can improve efficiency and reduce pesticide misuse. Also, with careful records, winter inventories can be reduced by only buying the amounts required.

The more information recorded, the more useful the records will be. Carry a notebook to the application site and record all necessary and helpful information. Do not try to memorize all the necessary items. A standard form can be used to ensure that all necessary data is obtained. Following is a list of the minimum information needed:

- Time of day and date of application
- Target pest(s)
- Equipment used
- Pesticide used:
  - Common name
  - Brand name
  - Formulation and percent of active ingredient
  - EPA registration numbers
  - Establishment and lot numbers (in case of cross-contamination or failure to control)
  - Total formulation added to tank or hopper
  - Amount of mixture used
  - Acres treated
- Additional comments:
  - Location
  - Weather
  - Applicator/crew chief/responsible individual
  - Severity of infestation

On every record form there should be a space left for ' **'additional comments.** ' ' Use this space to write down information for your personal use. This information can be used to improve your business either through better customer relations or by saving money. Record-keeping requirements may vary by State; check with the appropriate agency.

APPLICATOR SAFETY

The safety of forest pest applicators is assured only if proper procedures are followed. The proper procedures for handling, storing, transporting, and applying pesticides are presented in this section. This information is intended as a supplement to other pesticide safety instructional materials.

The Pesticide Label

The single most important source of information for safe pesticide use is the label. The label contains comprehensive information and instructions. Look for precautionary statements and warnings that are important in proper use. Detailed information appears for the application, storage, and disposal of the product. In addition, the label contains a telephone number of expert advice during an emergency and address of the manufacturer. Information regarding the brand name, chemical name, type of formulation, and EPA registration number are also included. These items are important to a physician in case of an accidental poisoning. The most important time in pesticide application is the time spent reading and understanding the pesticide label! Always read the label four times:

1. Before buying the pesticide.

2. Before preparing the material for use.

3. Before mixing and applying.

4. Before storing or disposing of the pesticide.

Before buying a pesticide, read the label to ensure that the chemical is properly labeled for your particular job. Make sure that it is suitable for your equipment, conditions, and site. Before preparing the chemical for use, read the label again for any warning or precautionary statements. Use all protective equipment recommended.

The label also specifies rates, methods of application, and sometimes compatibility with other chemicals or carriers such as diesel fuel. In addition, the label gives the waiting period for crops and entry by animals and any restrictions in the use of the chemical.

Mixing, Handling, and Applying Pesticides

The pesticide label contains precautionary statements, warnings, and often lists protective clothing and equipment required when using that pesticide. Read the label before mixing or applying.

Mixing

When handling a concentrated pesticide, precautions should always be taken. In their concentrated form, many pesticides may cause skin irritation and eye damage. Therefore, always use protective eye wear and neoprene or rubber gloves when mixing pesticides. Wear protective clothing such as long-sleeved shirts, long pants, and water-resistant boots. Be sure all skin abrasions or cuts are properly bandaged to prevent exposure before mixing chemicals.

On windy days, always pour pesticides by standing so that the wind comes from behind or from the side — never pour upwind. Keep the container spout below eye level. Small pumps can often be used to transfer pesticide, minimizing the risk of exposure.

Applying

When applying pesticides, avoid unnecessary exposure. Use protective clothing and equipment specified on the label. Bring wash water and detergent to the field in clearly-marked containers. Before application, use water to check equipment for leaks and proper calibration. When applying a pesticide, always stay upwind from the nozzle.

If pesticide is spilled on you, wash it off immediately. Also, take a change of clothes to the application site in case your clothes become contaminated. Before eating and smoking, always wash your hands and face thoroughly. Always wash contaminated clothes by themselves.

After application, clean and rinse the equipment. The best area for cleaning is on a wash rack or a concrete apron with a good sump. A second alterna-

tive is to apply the rinse water carefully on the site where the pesticide was applied, in compliance with the label.

When using pesticides, whether mixing, applying, or rinsing equipment after use, always be certain not to contaminate someone's water supply. Several precautions can be taken to avoid these problems. First, never apply near a well or other water source. When possible, use a nurse tank to mix only the pesticide needed for that day's work in the field. When filling from a well, use a separate pump equipped with check valves to prevent back siphoning.

Pesticide Disposal, Storage, and Transport

Disposal

After applying a pesticide, excess chemicals and empty containers should be disposed of or stored properly. Preventing pesticide surplus is the best way to minimize disposal problems. Before buying, make sure the pesticide is labeled for the intended use. Carefully estimate the amount of pesticide needed to complete the job and buy only what is needed.

Check the site and be sure weather conditions will allow proper application before mixing the pesticide. Also, mix only what is needed for that day.

Although steps can be taken to minimize any excess chemicals, empty containers must always be disposed of properly. After application, triple-rinse all empty containers. Pour rinsate back into the spray tank, not directly on the ground. Punch holes in non-returnable containers so they cannot be used again, and dispose of them in a sanitary landfill. Returnable containers are to be returned.

Storage

Proper storage of pesticides is essential to their safe use. The first step in proper storage is to designate an area where only pesticides are to be stored. This area should be secured with a lock and prominently posted at each entrance: **WARNING — PESTICIDES — KEEP OUT.** Ideally, the storage area should be made of fire-resistant materials, including a concrete floor. The storage area should be cool and dry and have an exhaust fan for proper ventilation.

Never store pesticides near food, feed, seed, or animals. Separate each type of chemical so that herbicides, fungicides, and insecticides are stored separately. Also, each formulation of pesticide should be grouped separately. Always store containers so that labels can be clearly seen. It is also a good practice to store containers off the ground on pallets to avoid moisture problems. An up-to-date inventory of all chemicals that are stored is recommended, including the date they were placed in storage and the date they are used.

The storage area should be kept clean and orderly. Absorptive clay, activated charcoal, pet litter, or sawdust should be readily available at the storage site to help clean any spill. A shovel, broom, and dustpan should also be available, and always keep a fire extinguisher in the area.

Transport

The following precautions can be helpful in safely transporting pesticides:

- Be sure the containers are not damaged before loading or during transport.
- Take only the amount needed for that day.
- Do not transport pesticides in the passenger section of a vehicle.
- Do not transport pesticides in the trunk of passenger cars or in trucks with wooden beds. Use a trailer to transport pesticides when using a car.
- Secure all containers so they will not move during transport, using ropes and straps. During the trip, check the containers periodically to be sure they have not shifted and spilled.
- When at the application site, park the truck or store the containers in the shade; direct sun can cause the containers to overheat, resulting in pressure build-up. A tarp can be used during transport.

Spill Procedures

If an accident occurs during transport and a minor spill results, administer first aid to anyone who may have been injured. Confine the spill if it starts to spread. Dig a dike around the area to contain the spill. Always take a shovel when hauling pesticides. Use an absorbent, such as those mentioned previously, to soak up the pesticide, or use clayey soil. Dispose of the contaminated absorbent as you would an excess pesticide.

Some accidents may result in a major spill — one that endangers people, property, or the environment. Your first priorities would be to administer first aid, contain the spill if possible, and then call the manufacturer. The number to call in case of an accident is prominently displayed on every label. The manufacturer will tell you which authorities to notify and what action to take.

Pesticide Toxicity

Toxicity Terms and Definitions

Toxicity — The measure of the ability of a chemical to injure or kill.

Exposure — Coming into contact with a chemical by swallowing, breathing or through contact with the skin.

Hazard — The degree of exposure combined with the level of toxicity.

LD_{50} — The amount (or lethal dosage) of a chemical required to kill 50 percent of the test animals.

Acute toxicity — A measure of the ability of a chemical to injure or kill from one exposure.

Chronic toxicity — The ability of a substance to injure or kill after long-term exposure.

Oral toxicity — The ability of a substance to injure or kill if swallowed.

Dermal toxicity — The ability of a substance to injure or kill if passed through unbroken skin.

PPM (parts per million) — A way to express the amount of pesticide in water, plants, food, or animals (1 ppm is equal to about 1 oz in 62,500 lb or 1 tablespoon in 3,906 gal),

PPB (parts per billion) Another expression of the amount of pesticide in water, plants, food, or animals that is 1,000 times LESS than a part per million (1 ppb is equal to about 1 oz in 62,500,000 lb or 1 tablespoon in 3,906,000 gal).

Half-life — The time required for one half of the initial concentration of a chemical to be degraded.

Volatility — The ability of a liquid to evaporate.

Measuring Toxicity

Toxicity, the capacity of a substance to injure or kill, varies with each chemical. Chemicals range from extremely toxic to essentially nontoxic. However, large enough amounts of almost any substance can be toxic. Knowing how toxicity tests are conducted is the key to understanding the toxicity of pesticides. Test animals (mice, rats, or rabbits) are fed a measured dose of a chemical. By increasing the amount of a chemical fed to test animals, the quantity required to kill 50 percent of the animals can be determined (LD_{50}). This dosage is usually referred to in terms of the weight of the chemical and the weight of the test animal. For example, the herbicide Roundup has an LD_{50} rating of 5,400 mg/kg. Approximately 1 pint of Roundup in the concentrated form would have to be swallowed for a 175-pound person to reach the LD_{50} dose.

Table 1 gives toxicity categories for pesticides, and table 2 provides LD_{50} ratings for common pesticides; other common substances that are frequently handled are listed for comparison. Table 3 provides estimates of the LD_{50} for a 175-pound person for a range of substances. This information implies that as the LD_{50} rating becomes larger, the substance becomes less toxic. For example, Product A with an LD_{50} rating of 40 mg/kg is much more toxic than Product B which has an LD_{50} rating of 4,000 mg/kg. Also note that many pesticides have acute toxicity ratings that are lower than many commonly used household compounds.

Many people wonder how a herbicide that successfully kills unwanted plants can have little toxic effect on humans. Plants differ from humans in many ways; researchers produce chemicals that interrupt a plant's function, but have little or no effect on humans. For example, in the photosynthetic process plants produce their own food by

Table 1. Toxicity categories for pesticides

Toxicity category	Signal word	Acute oral LD_{50}	Acute dermal LD_{50}	Acute inhalation LD_{50}	Eye effects	Skin effects	Estimated amount needed (orally) to kill the average person
		(mg/kg)	(mg/kg)	(mg/kg)			
I	DANGER	<50	<200	<0.2	Corrosive; cornea1 opacity not reversible within 7 days	Corrosive	A taste (<7 drops) to a teaspoonful
II	WARNING	50-500	200-2.000	0.2-2.0	Cornea1 opacity reversible within 7 days; irritation persisting for 7 days	Severe irritation at 72 hours	A teaspoonful to an ounce
III	CAUTION	500-5,000	2,000-20,000	2.0-20	No cornea1 opacity; irritation reversible within 7 days	Moderate irritation at 72 hours	An ounce to a pint
IV	CAUTION	>5,000	>20,000	>20	No irritation	Mild or slight irritation at 72 hours	Greater than a pint

> = Greater than.
< = Less than.

usihg carbon dioxide from the air, water from the soil, and sunlight. A chemical that blocks this process would kill a plant but may not affect humans since people cannot photosynthesize. Other plant processes, such as producing a particular amino acid that only plants can make, can be altered in a similar way, resulting in the death of plants, but having no effect on people.

Although the acute LD_{50} rating may indicate that the compound is relatively low in toxicity, it is wise to take precautions when mixing, handling, or applying any pesticides.

Table 2. Toxicities of forest pesticides and other products

Trade name	*Approximate acute oral LD_{50}*[1]	*Toxicity category*	*Signal word*[2]
	(mg/kg)		
Insecticides			
Cygon	255	II	WARNING
Dimlin	>4,640	III	CAUTION
Dursban	96	II	WARNING
Furadan	11	I	DANGER
Sevin	246	II	WARNING
Herbicides			
AAtrex 80W	5,100	IV	CAUTION
AAtrex 4L	1,075	III	CAUTION
Accord	>5,000	IV	CAUTION
Acme Super Brush Killer	1,810	III	CAUTION
Arsenal AC	>5,000	IV	CAUTION
Banvel	2,629	III	CAUTION
Banvel CST	>5,000	IV	CAUTION
Banvel 720	2,500	III	CAUTION
Chopper	>5,000	IV	CAUTION
Escort	>5,000	IV	CAUTION
Garlon 3A	1,847	III	DANGER[2]
Garlon 4	1,338	III	CAUTION
Krenite	24,400	IV	CAUTION
Krenite S	>5,000	IV	WARNING[2]
Oust	>5,000	IV	CAUTION
Pathway (Tordon 101R & RTU)	>5,000	IV	CAUTION
Pronone 10G	>5,000	IV	CAUTION
Tordon K	>5,000	IV	CAUTION
Tordon 101 Mixture	2,598	III	CAUTION
Velpar L	6,887	IV	DANGER[2]
Velpar ULW	1,200	III	DANGER[2]
Weedone CB	2,058	III	WARNING[2]
Weedone 170	2,000	III	CAUTION
Weedone 2, 4-DP	1,955	III	CAUTION
OTHER PRODUCTS FOR COMPARISON			
Gasoline	150	II	—
Caffeine	200	II	—
Asprin	1,240	III	—
Baking soda	3,500	III	—
Table salt	3,000	III	—

[1] *Unless otherwise indicated, values are for the formulated product (as in the container before any additional mixing).*
[2] *Severe eye irritant, which increases the severity of the signal word.*
> = Greater than.

Table 3. Estimated acute oral and dermal toxicity' (fluid ounces) of 18 chemicals for a 175-pound person

Trade name	*Approximate acute oral LD_{50}*[1]	*Toxicity category*	*Approximate acute dermal LD_{50}*[1]
	(fl ounces)		*(fl ounces)*
Nicotene	0.02	Extreme	N/A
Methyl parathion (80%)[3]	0.03	Extreme	1
Caffeine	0.21	Extreme	N/A
Lindane (20%)[3]	2	Moderate	11
Sevin (50%)	2	Moderate	3
Aspirin	3.5	Moderate	N/A
2,4-D	3.7	Moderate	4
Malathion (91%)	4	Moderate	12
Banvel	7	Moderate	6
Garlon	7	Moderate	11
Tordon 101[3]	8	Moderate	7
Table salt	9	Moderate	N/A
Banvel CST	14	Slight	6
Oust	14	Slight	14
Pronone 10G	14	Slight	N/A
Roundup	15	Slight	14
Tordon 101R	18	Slight	11
Velpar L	20	Slight	15

N/A = Not applicable.

[1] The estimated toxicity for the pesticide is based on the formulated product (as in the container before any additional mixing).

[2] Most LD50's are expressed as a range, reflecting experimental conditions, type of carrier, species of test animals, and precision of the tests, These estimates fall within the range and are only projections based on animal tests.

[3] Restricted-use pesticide.

PROTECTING THE ENVIRONMENT

Forest pesticides are registered only after the EPA has sufficient information that their proper use will not cause unreasonable harm to people or the environment, including wildlife and aquatic organisms. Special concern is placed on environmentally sensitive areas that are in or around treatment areas. These include streams, ponds, wells, special wildlife habitats, threatened and endangered species, homesites, orchards, crops, and beehives. Special precautions regarding such areas are often specified on the label. Problems usually occur when applicators do not follow label directions or they apply pesticides when conditions are not favorable. Damage to the environment usually is the result of one of the following:

- **Off-site application**
- **Off-site movement in air**
- **Off-site movement in water**
- **Pesticide persistence**

Each applicator must be aware of these problems and constantly work towards eliminating or minimizing adverse effects to the environment.

Off-site Application

To prevent off-site application or the accidental treatment of environmentally sensitive areas, mark boundaries clearly and use obvious, natural, or constructed features that can be readily identified by all applicators. Set up buffer strips as specified on labels and for protecting sensitive boundaries. Mark buffer strips around streams and ponds and take special care when treating sites near such areas. Every person doing the application should be informed and made aware of boundaries and their identification, as well as, any special precautions that should be used. Ground guidance for both aerial and ground application should be used whenever feasible to help the applicator to remain in the target area and make uniform applications.

Off-site Movement in Air

Chemicals may drift through the air from the area of application and cause considerable injury if they contact susceptible plants and animals, or sensitive humans. Movement through the air may result from spray drift or volatility.

Spray drift is the movement of airborne spray particles. The amount of spray drift depends upon (1) size of the droplets, (2) amount of wind, and (3) height above the ground that the spray is released. Droplet size depends mainly on pressure, design of the nozzle, and surface tension of the spray solution. In general, low pressures tend to produce large droplets and high pressures, small droplets. Small nozzle openings tend to produce small droplets and solutions possessing low surface tension tend to produce small droplets. To minimize drift, use the largest nozzle opening and lowest pressure combination that is effective.

Volatility refers to the tendency of a chemical to vaporize or give off fumes. The amount of fumes or vapors given off is related to the vapor pressure of the chemical and the temperature when applied. High temperatures will increase volatilization. Vapor drift is the movement of these vapors or fumes. The vapors may damage susceptible crops, cause allergic reactions by sensitive humans, and may reduce the effectiveness of the pesticide treatment due to loss. Volatilization can occur when ester formulations of forestry pesticides are applied during high temperatures. Formulations that are salts should be used to stop volatile losses when the form of the active ingredient is not important. Ester formulations should NOT be applied at high temperatures, such as greater than 90°F, when crop injury or offsite movement is a problem.

Granular materials, specialized spray equipment, low-drift adjuvants, and other precautions can reduce the chance of offsite movement. Select nonvolatile pesticides when sensitive species are nearby.

Off-site Movement in Water

Pesticides can find their way into aquatic environments from areas that have been treated unless proper precautions are followed. While pesticides may be present in very dilute quantities, they tend to be actively or passively magnified or concentrated by way of suspended particles that are dispersed in water.

Pesticides enter the aquatic environment by four principal mechanisms:

- **Point Source (e. g . ,** industrial effluents) — Pesticide contamination of the aquatic environment by point sources such as industrial effluents may result in immediate biological catastrophes or in long-term adverse effects.

- **Runoff** — Pesticides can move off a treatment area when dissolved in rainfall or on suspended particles in surface drainage water as overland flow (on compacted logging trails), stream water, and in ditch water.

- **Leaching** — Ground water or subsurface water may also be contaminated by pesticides. There are examples of contamination of wells and municipal water supplies.

- **Spillage, Accidents, and Careless Handling** — Pesticides may also enter water courses through inadvertent spillage (for example, around industrial sites). Other ways pesticides enter water include cleaning of application equipment in streams and careless aerial application of pesticidal chemicals. Back-siphoning into wells during loading should be prevented by using proper procedures and back-siphoning check valves.

The applicator must be knowledgeable of the factors that lead to runoff and leaching, while constantly guarding against spillage, accidents, and careless handling.

Solubility

Because there are many different chemical compositions of pesticides, one might expect them to vary considerably in the way they react with soil, water, and other substances. Pesticides vary in their potential for moving in soils and to groundwater. Three major characteristics influence such movement: solubility, persistence, and soil characteristics. The geology of the treatment area also influences possible movement into groundwater.

Chemicals vary greatly in water solubility; the greater the water solubility, the greater the potential for movement of the product to groundwater. Pesticides with low water solubility have less tendency to both move off-site with storm runoff or leach into the soil. More soluble compounds may leach deeply enough through sandy soils to contaminate groundwater. Soil-applied pesticides may wash or move into the water table more readily than foliar-applied materials.

Persistence

Although some chemicals degrade quickly, others breakdown slowly. The slowly degrading, or "persistent' ' materials, are more likely to reach groundwater over a period of time.

Soil Characteristics

Some chemicals become tightly attached ("strongly adsorbed") to soil particles and do not move in the soil. Some are not so strongly adsorbed and are more likely to move. Soil characteristics are also important in the movement of chemicals. Your local Soil Conservation Service office can help you determine which types of soil are in your area.

Three major soil characteristics affect chemical movement:

1. **Soil texture** — This is an indication of the relative proportions of sand, silt, and clay in the soil. Coarse, sandy soils generally allow water and solutes to move rapidly downward and offer few opportunities for adsorption. Finer-textured soils generally allow water to move at much slower rates and they contain more clay, silt, and organic matter to which pesticides may be adsorbed.
2. **Soil permeability** — A general measure of how fast water can move downward in a particular

soil. The more permeable soils must be carefully managed to prevent any form of chemical from reaching groundwater.

3. **Soil organic matter** — Influences how much water the soil can hold before movement occurs. Increasing organic matter will increase the water-holding capacity of the soil. Some pesticides may also be adsorbed onto organic matter.

Geology

Distance of groundwater from the surface is another important factor. If the groundwater is within a few feet of the soil surface, pollutants are more likely to reach it than if it occurs at greater depths.

Permeability of geological layers between the soil and ground water is also important. If surface water can move quickly to the groundwater, the potential for pollutants reaching groundwater is increased.

Sinkholes — Especially troublesome. Surface water often flows into sinkholes and disappears quickly into the groundwater. If a chemical is applied to an area that drains to a sinkhole, even moderate rain may carry some of the material directly to the groundwater.

Other Environmental Considerations

There are many species of beneficial forest insects, some of which are very abundant. Some 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 insects. Most are important food sources for birds and other small animals. Bees and certain other insects are important pollinators of some 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 nontarget life forms. Learn as much as possible about environmental hazards and potential nontarget impacts of pesticides. Select the pesticide and application method that will have the least adverse impact and still get the job done.

Fish or wildlife kills in any area should be reported to the appropriate State agency. They may want to investigate the reason for such a kill to help prevent future occurrences. Many factors other than pesticides can kill fish or wildlife.

Endangered Species Act

The Endangered Species Act provides:

- Legal protection for endangered and threatened species.
- That all federal agencies (EPA and USDA Forest Service, for example) ensure agency actions will not jeopardize the existence of any endangered species.

About 58 endangered species (17 percent of the current endangered species) live in forests in the United States. About 24 pesticides presently labeled for use in forests are considered to have an adverse effect on one or more of these endangered species. These numbers doubtless will change over time, but are given only to indicate that many endangered species live in forest habitats — and a number of pesticides will affect them. Every affected pesticide sold since 1988 shall have a warning on the label which prohibits pesticide use in the range (occupied habitat) of endangered species. Each State will have an enforcement plan to implement the Endangered Species Act in the near future. Consult with a county extension agent for the current regulations.

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