CHAPTER 13—INTEGRATED NURSERY PEST MANAGEMENT

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INTRODUCTION

Growth of Nurseries

An accelerated rate of reforestation in the United States in recent years has resulted in a concomitant increase in nursery seedling production. New nurseries are being established and old ones expanded throughout the country to meet the demand for tree seedlings. More than seventy State, industry, and Federal forest tree nurseries in the South now have an annual production exceeding 1 billion seedlings. This represents over 75 percent of the annual bareroot seedling production in the United States. Nurseries are also growing a wider variety of both conifer and hardwood species. For example, southern nurseries produce seedlings of 15 species of conifers and over 25 species of hardwoods.

This increased production and the greater number of tree species confront nursery managers with a wider variety of potential seedling losses to nursery pests (see table 13-1).The cost of control measures has also become high. For example, soil fumigation costs $800 or more per acre. The corresponding high value of seedlings has also significantly increased the impact of pest problems on both conifers and hardwoods. Seedlings may be worth $11 to $300 per thousand plants.

Seedling quality represents the most important economic aspect of field forestation. However, pine seedling costs ($11 to $25 per thousand seedlings) average less than 10 percent of total plantation establishment costs ($150 per acre). If the demand for future wood products is to be satisfied, both the quality and the quantity of southern pine seedlings must improve. Some of our highest forest resource values are represented in our nurseries.

Fortunately, seedling pest problems in the nursery are the exception rather than the rule. When pest problems do occur, nursery workers can employ an array of readily available techniques and procedures. The integration of the most suitable options into one concerted, harmonious effort is needed for an effective, efficient strategy for managing nursery pests.

Definition of INPM

Integrated Nursery Pest Management (INPM) is the reduction of pest problems in the nursery by employing decisions, plans, and a combination of management procedures in a coordinated pest management program. Briefly, INPM is an alternative decision support system for nursery management. This system, to be successful, requires a systematic, interdisciplinary approach. INPM plans and decisions include information from such related disciplines as soils science, silviculture, forest pathology, entomology, and weed science. The current INPM strategy emphasizes pest prevention, containment, and exclusion, rather than eradication.

Techniques and Procedures

Nursery pest management practices are closely related to and must be harmoniously used with prescribed cultural practices to be practical and effective. Nursery managers should remember that INPM practices can have both positive and negative effects on concurrent pest problems, as well as seedling production. The selection of the most effective, practical, and environmentally safe combination of INPM practices for the target pest problems is the key to successful pest management in a nursery.

Table 13-1. — Pests in southern conifer nurseries.

Common name	Portion[1] affected	Causal organism	Host
Necrosis	F	Pathogenic soil-borne fungi Nematodes Insects Nutrient deficiency Deficient or excessive water High temperatures	All conifers
Physiological (abiotic) damage	R,S,F	Adverse environmental factors Excessive or deficient nutrients Excessive or deficient water Pesticide toxicity	All conifers
Damping-off and root rot	R,S (basal)	*Pythium* spp. *Phytophthora* spp. *Fusarium* spp. *Cylindrocladium* spp. *Macrophomina phaseolina* *Sclerotium rolfsii* *Rhizoctonia solani*	All conifers, particularly pines and Fraser fir
Nematodes (root knot, dagger, pine cystoid, lance, lesion, stunt, and stubby-root)	R	*Meloidogyne* spp *Xiphinema* spp. *Meloidodera* spp. *Hoplolaimus* spp. *Pratylenchus* spp. *Tylenchorhynchus* spp.	Most conifers
Gall rusts	S	*Cronartium quercuum* f. sp. *fusiforme*	Slash, loblolly, and longleaf pines
		Cronartium quercuum	Southern hard pines—particularly Virginia and shortleaf
		Cronartium comandrae	Southern hard pines—particularly loblolly and shortleaf
		Cronartium comptoniae	Southern hard pines—particularly loblolly and shortleaf
		Endocronartium harknessii	Scots pine
Pitch canker	S	*Fusarium moniliforme* var. *subglutinans*	Slash, loblolly, shortleaf, and Virginia pines
Stem Canker	S	*Cylindrocladium* spp.	Eastern white pine
Foliage blights	F	*Scirrhia acicola*	Longleaf pine
		Rhizoctonia solani	Longleaf pine
		Phomopsis spp.	Eastern red cedar Arizona cypress
		Cercospora spp.	Eastern red cedar Arizona cypress
		Pestolotia spp. *Fusarium* spp.	Eastern white pine
		Cylindrocladium spp.	Eastern white pine
Needle casts and rusts	F	*Lophodermium* spp.	Scots pine
		Coleosporium spp.	Southern hard pines
Insects and Mites			
Weevils	R,S	*Hylobius pales* *Pachylobius picivorus*	All pines
Aphids and scales	S,F	Hemiptera (several families)	All conifers
Sawflies	F	*Diprion* spp. *Neodiprion* spp.	All pines
Spider mites	F	*Paratetranychus* spp. *Tetranychus* spp.	All conifers
Cutworms	R,S	*Phalaenidae* spp.	All conifers
Tip and shoot moths	S,F	*Rhyacionia* spp. *Eucosma* spp.	Southern hard pines
White grubs	R	*Phyllophaga* spp.	All conifers
Corn stalk borer	R,S	*Elasmopalpus lignosellus*	All conifers

[1]R roots
S stem
F foliage

FIRST CONSIDERATIONS

Prevention

An effective INPM prevention phase requires an information and education program with periodic training sessions. Make scheduled nursery inspections for existing and potential pest problems. Employ standardized State-administered, systematic quarantine measures to either avoid or minimize pest problems. An effective quarantine program will prevent the transport and spread of pathogenic fungi, nematodes, insects, and weed seeds into pest-free areas in the nursery and field forestation sites. These pathogenic organisms may be present on seedings, soil, water, equipment, or personnel. This procedure is probably the most effective and efficient pest management practice that is readily available and environmentally safe for nursery and forestation application. Preventive measures also frequently represent the only effective means of managing a nursery pest problem.

Pest Detection, Diagnosis, and Evaluation

Early pest detection, rapid diagnosis, and evaluation of existing or potential pest damage losses are prerequisites to successful nursery pest management. All nursery workers should be alert for early signs of pests. Report any signs of pests immediately to appropriate State, Federal, industry, or university pest specialists to facilitate rapid diagnosis and evaluation of the pest problem. This step will permit the selection and timely application of the most effective, efficient, and environmentally safe INPM action for problems before they become unmanageable.

SITE SELECTION

Selection of the nursery site is the first and probably the most important cultural practice for consideration in the nursery pest management plan. Select new locations or expand existing ones only after consideration of the following factors and their relationship to pest management: soil type, texture, pH, and drainage; past cropping history and present indications of pest occurrence; and adequate supply of uncontaminated water with sufficient mineral composition and proper pH level. The soil type for most tree species should be of a coarse texture, primarily sand with some silt and a low clay content. The soil profile should not have any impermeable subsoil. This type of soil will promote good tillage, effective soil fumigation, and good drainage. Pre-emergence damping-off, caused by several soil-borne fungi, is less severe in coarser soils with good drainage.

Seedbeds should also be designed and constructed to drain water away from the seedlings. Fine-textured soils with poor internal drainage, and improper seedbed design and construction, impede soil fumigation and encourage the development and buildup of soil fungi, nematodes, and weeds. The pH of soil and irrigation water can affect the development of soil-borne fungal diseases. Pre- and post-emergence damping-off problems often occur in conifers when the soil pH exceeds 6.0. Reduce the soil pH to a range of 5.0 to 5.5 to help avoid such problems. Avoid contaminated water sources because they often contain pathogenic fungi, nematodes, insects, weed seeds, herbicides, and chemicals detrimental to quality seedling production. See chapter 2 for a more detailed discussion of Site Selection.

MANAGEMENT PRACTICES

Crop Rotation

Crop rotation is used in INPM programs to reduce seedling losses. Fungi, insects, nematodes, and weeds may increase substantially during prolonged association with any susceptible host. These pests are often a problem where continuous cropping is practiced without rotation. Alternating susceptible and nonsusceptible crops in the proper sequence will often avoid severe damage to any particular crop. The alternation of cover crops with seedling production is standard practice in many forest tree nurseries.

Cover Crops

Cover crops are used for various purposes, such as erosion control and organic matter buildup. Cover crop species vary in their susceptibility to different nursery pests. Some cover crop species are highly susceptible and promote the buildup of specific soil pathogens. For example, corn, peas, soybeans, and sorghum are susceptible cover crop hosts for the charcoal or black root rot fungus of conifers, while legumes such as soybeans and alfalfa are susceptible to the cylindrocladium root rot fungus of hardwoods.

Cover crops should be plowed under at a minimum of 2 months before soil fumigation to afford adequate decomposition. Green manure cover crops and nondecomposed organic material may adsorb or otherwise deactivate large quantities of chemicals (e.g., methyl bromide) added to the soil, thereby reducing the pest reduction effectiveness. Organic matter amendments may reduce damage by soil pathogens because organic matter added to the soil promotes the increase of soil saprophytes and competitors—organisms that effectively compete with certain soil pathogens. Organic amendments also have a positive biodegrading effect on residual toxic chemicals in the soil.

Organic Matter Amendments

Maintenance of organic matter in sandy soils in many southern nurseries is a problem. Annual applications of organic amendments help to improve tilth, nutrient, and water retention, and soil aeration. All of these soil factors are necessary for good, rapid root development and subsequent mycorrhizal development. Conifers with healthy root systems and extensive ectomycorrhizal development are more resistant to certain soil-borne pathogens. However, precautions are required concerning the type and composition of the organic amendments. For example, fresh sawdust or pine bark may have adverse effects on tree seedling development. By encouraging the development of certain micro-organisms that decompose the organic matter in the soils, much of the available nitrogen is tied up and rendered unavailable to the seedlings. As mentioned earlier for the mulch materials, organic amendments such as pine needles, leaves, straw, and organic waste can harbor harmful fungi, nematodes, weed seeds, insects, or chemicals. Organic amendments are discussed in greater detail in Chapter 1.

Species Selection

Consideration should be given to species-site requirements in the nursery similar to those required for field plantings. Conifers and hardwoods often have different site requirements, soil microbiological associations, and cultural procedures. When conifers and hardwoods are produced in the same nursery, you should adjust the INPM program to account for the variations in resistance of the conifer and hardwood species to particular pests.

Control of the Soil pH

Your control of the soil pH will help combat certain diseases caused by soilborne fungi. As previously stated, pH levels above 6 are conducive to the development of damping-off problems. The addition of prescribed amounts of elemental sulfur will effectively lower soil pH and often reduce losses from damping-off of conifer seedlings (see chapter 12). Some nursery soils have undesirably low pH levels below 5.0 for conifers, or 6.0 for hardwoods. Add lime to increase the pH of these soils. The pH of irrigation water can be lowered, when needed, by metering prescribed amounts of sulfuric or phosphoric acid into the irrigation system.

Seedbed Sowing Dates

The dates nursery seedbeds are sown are an important factor in reducing seedling losses caused by soil-borne pathogenic fungi and the environment. Cold, moist soils, characteristic of early spring conditions, are conducive to the development and growth of *Pythium* and *Phytophthora* fungi that cause damping-off of germinating seedlings. A delay in spring seeding will often avoid damping-off problems. In warmer climates, the high soil surface temperatures that predominate in late spring frequently cause a high incidence of sun scald that kills young, tender seedlings. Early spring seeding in these areas is recommended. Fall sowing is also an alternative choice to avoid sun scald problems of several species. A more detailed discussion is presented in chapter 6.

Seedbed Density

Control of seedbed density will reduce certain pest problems. When seedbeds are too dense, increased competition among seedlings for the available soil nutrients and water frequently reduces seedling growth and vigor—and increases their susceptibility to damage from certain pathogenic fungi, nematodes, and insects. In addition, dense seedbeds encourage heavy growth of foliage, which reduces air circulation. As a result, a more favorable microclimate exists for fungi that cause foliage diseases. The present increased demand for seedlings in accelerated reforestation programs suggests a possible trend to denser nursery seedbeds. Corresponding increases in pest problems and seedling losses can be anticipated. A compromise will be needed to adjust seedling density to minimize pest losses and still meet production goals (see chapter 6).

Mulches

Carefully select and use mulches to avoid the introduction and development of pest problems. Pine needles, sawdust, and grain straw mulches may contain pathogenic fungus propagules and weed seeds that later invade susceptible seedlings and soil. If such materials are used for mulch, fumigate them under a tarp before use on the seedbeds. Methyl bromide, 98 percent; chloropicrin, 2 percent (MC-2) or methyl bromide, 67 percent; and chloropicrin, 33 percent (MC-33) used at a dosage rate of 1 pound per cubic yard of material provides excellent pest control. Aerate the mulch by removing the tarp at least 48 hours before use. (See chapter 6 for additional suggestions.) In addition, precautions may be warranted when using commercial fiber mulches, particularly as seedling packing material, as they have recently been found to harbor harmful yeasts that damage the seedlings in storage. (See chapter 10 for details.)

Fertilization

Fertilizer composition, rate, timing, and application methods can have important effects on both biotic (insects and fungi) and abiotic (physiological) disease problems, as well as associated soil fungi beneficial to seedlings.

Suboptimal rates, inadequate formulation, and improper use of fertilizer often result in seedling stunting, foliage yellowing (summer chlorosis frequently caused by insufficient nitrogen and/or iron), poor root development, and subsequent mortality. Seedlings in this condition are considerably more susceptible to certain soil and foliage parasitic fungi, nematodes, and insects. Also, excessive rates and improper timing of application will often result in foliage "burning" or browning and/or root mortality. Excessive applications of nitrogen in early spring in soils deficient in calcium and phosphorus may increase seedling damage by damping-off fungi. Infection and damage by the fusiform rust fungus also may increase with increased nitrogen and phosphorus fertilization. Excessive levels of phosphorus (above 200 lbs. available P_2O_5 per acre) have been shown to inhibit formation of ectomycorrhizae on conifers and endomycorrhizae on hardwoods.

Irrigation

Inadequate, excessive, or improper irrigation may favor the development and intensification of pest problems in the nursery. As with inadequate fertilization, inadequate water may cause seedling yellowing, stunting, and death—particularly during hot, dry weather. In addition, several species of conifers and some hardwood seedlings growing under conditions of inadequate soil moisture and temperatures above 90 °F are much more susceptible to the fungi that cause charcoal or black root rot. Excessive water may inhibit soil aeration, kill roots, and result in damage by soil-borne pathogenic fungi, such as *Pythium Phytophthora,* and also nematodes. Repeated, excessive irrigation may increase the incidence of foliage disease on hardwood and conifer seedlings (see chapter 11).

Temperature

Temperature is one of the most difficult environmental factors to control in nursery seedbeds. However, as previously stated, both high and low soil and air temperatures have significant effects on a number of pest problems, as well as seed germination and seedling growth. High temperatures can be decreased with irrigation. Occasionally, species such as eastern white pine and Fraser fir need shade. Problems from low soil temperatures in early spring are most easily avoided by delaying seedbed sowing to allow adequate soil temperatures to develop for maximum seed germination and early seedling growth.

Soil Drainage

Good soil drainage in seedbeds is essential for minimizing diseases caused by soilborne fungi such as *Pythium* and *Phytophthora.* Elevation and crowning of seedbeds will correct minor soil drainage problems. Subsoiling and installation of drainage tiles are frequently required for areas with poor soil drainage. Surface water collection and resulting stagnation in low spots of nursery beds can be eliminated by proper leveling and reshaping of seedbeds. Take precautions when beds are shaped, to avoid the development of low areas or drop-offs on the bed ends. Orientation of bed direction to promote proper water runoff will also decrease drainage problems that encourage pest development.

Eradicate Alternate Hosts

Some nursery pests, such as the rust fungi, are obligate parasites and require an alternate host to complete their life cycle. Where feasible and practical, eliminate these alternate hosts in and around the nursery to minimize these disease problems. The white pine blister rust fungus, *Cronartium ribicola,* with the *Ribes* or currant as alternate hosts, and the fusiform rust fungus, *Cronartium quercuum* f. sp. *fusiforme*, with the oaks as alternate hosts, can be reduced in this manner. However, pest eradication practices are frequently impractical, uneconomical, and provide erratic results—particularly where fungi with relatively long-range infective spores are involved.

Windbreak Species

Tree species used for windbreaks should be neither alternate hosts of, nor susceptible to, potential seedling pests. The use of similar windbreak and seedling crop species may provide abundant supplies of fungus inoculum and insect pests that may readily spread to adjoining nursery seedlings. Existing, susceptible windbreak species may require either sanitation pruning, or elimination in some cases, to avoid the buildup of reservoirs of fungus inoculum and insects.

Sanitation

Sanitation is an important practice in nursery pest management to prevent the spread of pest problems within the nursery and to field plantings. This practice includes roguing diseased or insect-infested seedlings and weeds in nursery seedbeds, along with the elimination of pest host plants and weeds in and around the nursery to reduce fungi, insects, and weeds.

Seedling Grading and Culling

This practice may be required to minimize the transport of pest-infested seedlings to field planting sites. Grading of seedlings before packaging will help detect inconspicuous root-rot diseases and other diseases such as the stem rusts and certain foliage diseases. These diseases often are not detectable until late in the growing season.

Diseases that are erratically distributed in nursery seedbeds make attempts at bed grading and culling considerably more difficult and ineffective than when seedlings are graded in the packing shed. Nursery managers who have eliminated seedling grading in the packing shed should consider reinstating this practice when severe pest problems appear.

BIOLOGICAL AGENTS

Although biological techniques represent one of the most desirable pest management practices, effective practical applications in nurseries have been very limited. The most successful example has been the recent use of selected ecto- and endomycorrhizal fungi in conifer and hardwood nurseries, respectively.

Parasites and Predators

These biological agents may assume significant roles in the control of pests, particularly insects in the nursery. They are present in nature and their development usually coincides with that of the pests. Unfortunately, the manipulation and introduction of parasites and predators as biological management agents has shown very limited success.

Competitive and Saprophytic Fungi and Bacteria

Most fungi and bacteria in the nursery are beneficial rather than harmful. In fact, certain types of fungi and bacteria are required for successful tree seedling and cover crop production. Most fungi and bacteria are either soil organic matter saprophytes or nitrification agents. Some of these organisms are beneficial as antagonists or competitors in association with soil-borne pathogenic fungi. Without sufficient members of these beneficial soil organisms, the processes of organic matter decomposition and nutrient fixation are greatly impeded. Most of these types of fungi and bacteria are the pioneer colonizers of recently fumigated soil. Some of these soilborne fungi, e.g., *Trichoderma* spp., are highly antagonistic and competitive against subsequent invasions of pathogenic fungi.

Mycorrhizae

All forest tree seedlings form mycorrhizae with specific fungi resulting in a mutually beneficial symbiosis. Two general types of mycorrhizae are found in forest tree nurseries: ectomycorrhizae, occurring primarily on conifer species and some hardwoods (oaks), and endomycorrhizae, occurring primarily on other hardwood species. The symbiotic association between the mycorrhizal fungus and the tree root is the rule rather than the exception in nature and is required for the successful production of the majority, if not all, conifer and hardwood seedling species. The ectomycorrhizal fungi are readily disseminated by windborne spores. Consequently, even in nurseries employing soil fumigation, spore dissemination assures rapid recolonization of the soil by these fungi. Mycorrhizal deficiencies in most conifer nurseries are rarely a problem.

The endomycorrhizal fungi, however, are not wind disseminated, but must rely on soil and water movement as passive fungus propagule dispersal methods to recolonize noninfested areas. Therefore, endomycorrhizal deficiencies often occur after preplant soil fumigation of hardwood nursery seedbeds. Extensive research and field evaluations are presently aimed at the practical application of specific ecto- and endomycorrhizal fungi to conifer and hardwood nurseries. The endomycorrhizal fungi, with their obligate parasitism and subsurface spore production, require different nursery application and cultural practices than do the ectomycorrhizal fungi, with their prolific characteristics. A more complete discussion of mycorrhizae is included in chapter 1.

Pest Resistant Species and Varieties

Considerable variations in pest resistance are demonstrated between species and varieties of conifer and hardwood seedlings. Examples of these inherited characteristics include the variable resistance patterns of pine species to the rusts (fusiform and white pine blister rust) and foliage diseases (brown spot and *Lophodermium*) along with species varietal resistance patterns to specific pest problems, such as *Lophodermium* needle cast on Scots pine. The application of inherited disease resistance patterns has been very effective in the selection, development, and breeding of rust-resistant pine trees.

For several years, the Forest Service has conducted extensive research, field evaluations, and controlled testing on pine rust diseases, such as fusiform rust in the South, and white pine blister rust in the West and North Central States. Similar work has also been conducted by several public and private agencies on cottonwood leaf rust diseases. Seeds and cuttings from improved rust-resistant seed orchards are becoming available for the production of rust-resistant pine (fusiform and white pine blister rust) and hardwood (cottonwood leaf rust) seedlings that will be planted on high rust-hazard sites.

CHEMICAL TREATMENTS

Chemical treatments involve a variety of pre- and postplanting pesticide applications. Although considered a significant integral component of INPM, this practice should be primarily used only when other INPM practices are either not available or have failed to produce satisfactory control of pests. Refer to Chapter 18—section on Pesticide Safety for the safe handling of pesticides.

Soil Fumigation

Soil fumigation is the most effective chemical control measure for preventing diseases caused by soil fungi, insects, and nematodes. Broad spectrum fumigants also control most weeds. Several soil fumigants are commercially available and registered by the U.S. Environmental Protection Agency for preplant nursery soil treatments. The most effective broad-spectrum soil fumigants used against many soil pests—particularly soil-borne pathogenic fungi, insects, and nematodes—are the methyl bromide-chloropicrin formulations. The methyl bromide (67 percent) chloropicrin (33 percent) formulation is most effective in controlling root rot disease fungi with tough, resistant-spore stages. Examples include charcoal or black root rot on conifers and cylindrocladium root rot on hardwoods.

Effective soil fumigation can be more consistently obtained by considering and using the basic physical (soil), biological (target organisms), and chemical (fumigant) factors. They are outlined in Appendix 13-1. Soil fumigation is discussed in more detail in chapter 4.

Seed Treatment

Most pine seeds are prepared for planting in southern nurseries by coating them with a fungicide-latex sticker chemical mixture to retard damping-off damage and to repel birds. The EPA-registered fungicide most commonly used is thiram at the rate of 2 pounds of active ingredient (liquid or wettable powder formulations) and 5 ounces of undiluted commercial latex sticker per 100 pounds of seed. Detailed instructions for the treatment of seeds are included in chapter 6. Seed treatment with Bayleton® for fusiform rust control is included in appendix 13-3.

Soil Pesticides

Pesticides are occasionally needed to help control several soil pests, such as pre- and post-emergence damping-off, root diseases, insects, and nematodes. These pests may develop after either ineffective soil fumigation or by reinvasion of fumigated soil. Several pesticides are available for use against different pests. The majority are applied as postemergence drenches in water solutions followed by adequate irrigation (i.e., 1/2 inch of water) to move the pesticide down into the seedling root zones.

Other techniques include pre- or post-emergence broadcast or row-drill nursery applications, and incorporation into container seedling mixes in powder, granular or liquid mixtures. Seedling dips (roots or foliage) in selected pesticides can prevent or reduce pest damage in field plantings. The pesticide treatments should begin as soon as the first symptoms are detected for maximum effectiveness. Repeated treatments, however, are often needed to control nursery pests.

Protective Foliage Sprays

Protective foliage sprays are often needed to control stem rust and foliage diseases such as fusiform rust of southern pines and brown spot needle blight of longleaf pine. Sprays are also used for several other foliage diseases and insects on both conifer and hardwood seedlings. Effective control of pests requires complete and continuous coverage of the susceptible foliage with the nonsystemic protective pesticides. For example, ferbam has been sprayed 30 to 40 times routinely from seed germination to June 15 to control fusiform rust on slash and loblolly pine seedlings in southern nurseries.

Systemic Pesticides

During recent years, a number of new systemic pesticides have given effective, efficient, and economical control of several nursery fungi and insects. As the term indicates, the systemic pesticides have the unique characteristic and primary advantage of translocation into and between various plant parts, i.e., soil to roots, roots to shoots, and shoot to roots. This kind of coverage can save money because pesticides can be used less often in smaller amounts, and provide greater plant coverage.

Some systemic pesticides, in addition to shielding seedlings from future attacks, also act against pests already damaging seedlings. For example, the recently developed systemic fungicide, triadimefon (Bayleton®), has shown highly effective protective and curative action against the fusiform rust fungus in laboratory, greenhouse, and nursery field tests. Effective control of rust has been obtained with only two or three equally-spaced treatments during the rust infection season on pine seedlings (seed germination—June 15) in high fusiform rust-hazard nurseries in the South.

Experimental and special use pesticide labels (24-C) have been obtained in 10 high-rust-hazard States. Additional efficacy, phytotoxicity, and environmental impact data is being collected by several cooperating agencies for registration of triadimefon by EPA for the control of fusiform rust in southern nurseries. (See appendices 13-2 and 13-3).

SEEDBORNE PESTS

Tree seeds, including seed-orchard seed, have recently been shown to harbor pathogenic fungi. Even high germination capacity seedlots with "high quality" seed may contain disease organisms. As much as 40 percent of an apparently healthy seed lot has been shown to contain internal fungus pathogens in addition to external seedcoat contaminants. A primary disadvantage to nursery workers resulting from these "invisible" seed pests stems from the fact that the pests are hidden internally in many seeds that look normal. Seeds containing these fungi may readily germinate, but the developing seedling may be either killed by damping-off or, more significantly, destroyed in the subsequent seedling crop or field plantings. The most effective method to minimize these seedborne fungi is to test each seedlot before nursery sowing. Research is in progress to find effective and practical methods to reduce seed and seedling losses caused by these fungi. (Seed handling, testing, and storage is discussed in chapter 5.)

SUMMARY

The INPM techniques and procedures presented in this chapter provide the necessary information to enable the nursery manager to evaluate alternative plans and select the most effective, practical, and environmentally safe practices for a successful, integrated pest management program.

When selecting nursery sites, one should place top priority on soil texture, soil pH, and soil drainage to minimize adverse effects in growing seedlings and to reduce future pest problems.

Proper cultural practices help minimize pest problems because vigorous plants are usually less susceptible to pests. Root diseases usually cause the most serious economic losses in southern nurseries. An integrated program of fumigation, crop rotation, and proper selection of cover crops can significantly reduce losses from root diseases, as well as reduce insect damage and weed control expenses.

For each seedling species one should check the literature to determine which soil pH range provides optimum seedling growth. Specific soil pH adjustments may be warranted for sensitive species.

Proper sowing date and proper seedbed density can help minimize losses from damping-off organisms and reduce losses from root rot fungi, nematodes, and insects. Dense seedbeds often provide a favorable microclimate for foliage diseases.

Proper fertilizer composition, rates, time, and application methods help minimize pest problems. Early spring applications of nitrogen on soils deficient in calcium and phosphorus may increase damping-off incidence. Excessive available phosphorus will inhibit mycorrhizae development on conifer and hardwood seedlings.

Proper watering regimes minimize pest losses. Conifers are more susceptible to black root rot when growing under moisture stress. Excess water may increase root damage by *Pythium*, *Phytophthora*, and nematodes.

Where feasible and practical, eliminate alternate hosts of recurrent damaging pests. Tree species used for windbreaks should not be alternate hosts or susceptible to common nursery pests.

Cover crops are used primarily for soil erosion control and organic matter buildup and can have either a positive or negative effect on soil pathogens. Cover crops should be plowed under at least 2 months before fumigation to allow time for sufficient decomposition. Soil amendments, such as fresh sawdust or pine bark may cause a nutrient drain. The soil microflora that decompose these materials often use substantial quantities of nutrients which may reduce seedling growth rates. If such materials are used, additional applications of nitrogen fertilizer are usually required to balance the carbon/nitrogen ratio.

The majority of micro-organisms in the soil are beneficial. Without sufficient microflora populations, organic matter decomposition, nutrient availability, and mycorrhizae development are greatly impeded. Soil fumigation reduces the quantity of ectomycorrhizal fungi; however, the soil population is usually sufficiently replenished by the end of the first growing season as a result of their ability to recolonize fumigated soil.

Pest-resistant pine and hardwood species are being developed as an effective long-range INPM strategy. Fusiform, white pine blister, and cottonwood rusts will be minimized by the production of rust-resistant tree seedlings that will be planted in high rust-hazard sites.

Soil fumigation is the most effective chemical pest management practice for control of root diseases, insects, and nematodes. To minimize additional pest problems, mulch materials should be fumigated and aerated a minimum of 48 hours before use in nursery beds. Soil pesticide treatments may be needed occasionally, usually when ineffective fumigation does not control damping-off and root diseases.

Protective foliage sprays are being replaced by systemic pesticides. A number of systemic pesticides are available that will control diseases and insects. These chemicals are translocated throughout plant parts, which afford cost-savings in application frequency, plant coverage, and pesticide use. Systemic chemicals may also help reduce the losses from seed-borne pests.

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APPENDIX 13-1

Suggested guidelines and precautions for effective soil fumigation with methyl bromide.[1]

Soil fumigation factors	Guidelines and precautions
Soil preparation	Work into fine, loose, friable condition to minimum depth of 8 to 10 inches. Soil should be as free of clods as possible.
Organic matter	Do not use nondecayed organic matter. Organic matter can render fumigant ineffective and harbor fungi and nematodes. Cut or chop green organic matter into the soil a minimum of 3 to 4 weeks prior to fumigation.
Soil moisture	Soil moisture neither too high nor too low. Light sandy soils—slightly below field capacity.[2] Heavy clay soils—50-75 percent field capacity.
Soil temperature	Soil temperature above 50°F at 6-inch depth. Air and soil temperatures not usually correlated.
Soil fumigants and target pests	Mixtures of 98% methyl bromide/2% chloropicrin fumigant: broad spectrum for nematodes, weeds, and most soilborne fungi. Mixtures of 67% methyl bromide/33% chloropicrin fumigant: particularly effective against soilborne fungi with tough resistant stages. Mixtures of 98% methyl bromide/2% chloropicrin diluted with 30% solvent inert ingredients: least effective against soilborne fungi.
Calibrating and monitoring soil fumigation equipment	Fumigant dosage = concentration X time. Dosage determined by injector nozzle size, fumigant pressure, and tractor speed. Fumigant injected at minimum 8-inch soil depth. Maintain constant pressure, tractor speed, and fumigant flow through all nozzles for uniform, effective coverage.
Soil tarping	Apply minimum 2-mil-thickness clear polyethylene tarp immediately after fumigation for maximum effectiveness. Alternate strips require longer fumigation and time intervals and afford opportunity for contamination from adjacent nonfumigated soil strips. Solid tarping requires shorter fumigation time interval and minimizes opportunity for soil contamination. Repair and seal any holes and open glue joints immediately.
Fumigation exposure period	See fumigant label for recommendations. Minimum of 48 hours at soil temperature above 60°F at 6-inch depth. At lower temperatures and during wet weather (following fumigation) double the exposure period.
Fumigation aeration period	See fumigant label for recommendations. Minimum of 48-72 hours; varies with fumigant, soil, temperature, moisture, and crop to be planted. Double aeration period in wet weather or at temperatures below 60°F.
Extended aeration for seedbeds receiving artificial inoculations of mycorrhizal fungi	Aerate soil at least 3 weeks following mixture of 67% methyl bromide/33% chloropicrin fumigation. This strong fumigant has extended residual toxicity to all soil fungi, including those which form mycorrhizae.
Contamination of fumigated soil	Avoid possible contamination by movement of soil, plants, mulches, etc., into fumigated areas. Clean, by steam or equivalent, all equipment: plows, bed shapers, tractor tires, etc. Avoid transplanting from nonfumigated soils.
Fumigation of mulch materials	Prefumigate mulch materials such as pine needles, straw, and sawdust with mixture of 67% methyl bromide/33% chloropicrin or mixture of 98% methyl bromide/2% chloropicrin formulations at dosage rate of one lb/yd³. Tightly compacted or baled materials should be a maximum of 18 inches deep. Loose pine needles, straw, etc., may be 3-4 feet deep. Fumigation procedures and precautions (tarping, temperature, moisture, exposure, aeration periods, *etc.*) are same as for soil fumigation.
Soil nutrient alterations	Level of soluble salts and ammonia nitrogen may be increased due to decreased populations of nitrifying bacteria. Do not use ammonia fertilizers on plants requiring nitrates or those sensitive to ammonia. Apply only nitrate fertilizers until seedlings are established and soil temperature is above 65°F. Base your fertilizer applications on soil tests made after fumigation.
Water requirements	Water requirements per unit of plant production are generally less. Water requirements per acre are increased due to generally larger plants and increased production.
Cover crops	Green manure cover crop plants such as corn, peas, and soybeans are highly susceptible hosts for *M. phaseolina*. Grain crops such as millet or rye are considered nonhosts.
Safety	The methyl bromide/chloropicrin formulations are highly toxic to animals (including humans) and plants. Handle fumigants with care and only by certified competent personnel. **ALWAYS READ FUMIGANT LABEL PRIOR TO USE AND FOLLOW ALL DIRECTIONS AND PRECAUTIONS CLOSELY.**

[1]Source: Seymour, C. P.; Cordell, C.E. Southern Journal of Applied Forestry. 3(3): 104-108; 1979.
[2]*Water-holding capacity of the soil against the force of gravity.*

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C. P. Seymour and C. E. Cordell

APPENDIX 13-2

Bayleton® for Fusiform Rust Control—An Update of Research Findings[1]

by

S.J. Rowan and W.D. Kelley[2]

Abstract.—Based on a series of studies, a spray schedule is presented that should improve the efficacy of Bayleton for fusiform rust control in nurseries. Many adjuvants appear to be useful in formulations with Bayleton. A seed soak treatment is an approved use in some states under the 24-C label. Use of Bayleton as a seed treatment combined with foliar sprays will improve rust control during the critical germination period. Observations of roots of seedlings at time of lifting indicate little, if any, suppression of mycorrhizal development of foliar sprays of Bayleton.

Although Bayleton (triadimefon) has provided excellent control of fusiform rust in greenhouse and nursery studies, operational use of this fungicide in nurseries using the recommended spray schedule resulted in unacceptable levels of rust losses in some nurseries. Among 32 nurseries using Bayleton on their 1981-1982 crops, 15 reported no rust (the desired goal), 15 reported less than 1 percent, and 2 reported less than 2 percent rust. In the same crop year, however, plots in Florida's Munson nursery had approximately 7 percent infection after 3 foliar sprays of Bayleton and plots at St. Joe Paper Company's nursery in Florida had approximately 3 percent infection after 3 foliar sprays[3].

In attempts to improve the control obtained with Bayleton, a series of studies were conducted. Results of these studies either have been or are being published elsewhere. One study was designed to determine if Bayleton foliar sprays, like ferbam sprays, must dry before irrigation or rain for rust control. Table 1 shows simulated rain 5 minutes or more after application of sprays did not reduce efficacy of the treatment. Theoretically, however, more fungicide would be on and in pine seedling tissues if sprays were allowed to dry fully before irrigating seedbeds.

A total of 18 adjuvants were compared for use in formulations with Bayleton for control of fusiform rust in pine seedlings. Results of this test show that, without rain, all tested adjuvants were of equal quality. After 5 cm of rain, however, two of the 18 adjuvants, Bond spreader sticker and Ortho X-77, were slightly inferior.

Table 1.—Effects of simulated rain on efficacy of Bayleton sprays for control of fusiform rust

Time after spray (Minutes)	Seedlings infected[1] (Percent)
Nonsprayed check	86.8 a
0.25	1.2 b
1	1.2 b
5	0.0 c
15	0.0 c
30	0.0 c
60	0.0 c
120	0.0 c

[1]Means followed by a common letter do not differ (P=0.05) according to Duncan's Multiple Range Test.

The high speed at which Bayleton is absorbed by pine seedling tissues (table 2) probably explains why the adjuvants varied so little. Proper agitation of the spray mix during preparation and application should make most, if not all, adjuvants tested of equal value when used with Bayleton.

In a test to determine how effective a seed soak treatment was for control of fusiform rust, significant reduction in rust incidence was evident through 35 days after seedling emergence (table 3) and complete control by the seed treatment was obtained through 7 days.

Because a seed soak is a preventative measure and foliar sprays have both preventative and eradicative properties, it was reasoned that the combination of the two treatments may increase the degree of rust control. A test was therefore devised in which foliar sprays were applied at differing time intervals before and after inoculation with the rust fungus to seedlings originating from both treated and nontreated seeds. Results of this study show that foliar sprays alone will prevent infections for up to 28 days after spray applications (table 4) and will eradicate infections up to 7 days old. When both a foliar spray and seed treatment are combined, however, infections up to 14 days old were eradicated. Therefore, when seeds are treated, seedlings need not be sprayed until 14 days after emergence begins.

Bayleton did not eradicate infections on 4 year old loblolly pines when applied topically (table 5), giving additional proof that this fungicide will eradicate only the very young infections.

Bayleton is registered for use in forest nurseries as foliar sprays, and is approved under the 24-C label for use as

[1]Source: Proceedings, 1982 Southern Nursery Conference. Tech. Pub. R-8-TP-4. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region; 1982: 202-211.

[2]Respectively, Principal Research Plant Pathologist, Southeastern Forest Experiment Station, Forestry Sciences Laboratory, Carlton Street, Athens GA 30602 and Professor, Department of Botany, Plant Pathology and Microbiology, Auburn University Agriculture Experiment Station, Auburn, AL 36830.

[3]Personal Communication, Dr. Ed Bernard, Florida Division of Forestry, P. O. Box 1269, Gainesville, FL 32602.

Table 2.—Efficacy of 18 adjuvants in Bayleton sprays for control of fusiform rust of loblolly pine seedlings when applied 2 days before seedlings were exposed to 0 and 5 cm of artificial rain[1]

		Rainfall (cm)	
	Rate (ml)	0	5
Adjuvant	per liter	% Galled seedlings	
Nu-film-17	1.25	0.0a[2]	0.0a
Security Spreader-Sticker	0.63	0.0a	0.0a
Exhalt-800	1.25	0.0a	0.0a
Triton X-45	1.25	0.0a	0.0a
Triton X-100	1.25	0.0a	0.0a
Atlas Sur-fac	5.0	0.0a	0.0a
Ortho X-77	0.47	0.0a	1.1b
Olde Worlde	1.25	0.0a	0.0a
Plantgard	200.0	0.0a	0.0a
Bio-film	0.47	0.0a	0.0a
Plyac	1.25	0.0a	0.0a
Dupont Spreader-Sticker	0.31	0.0a	0.0a
Ortho-Chevron Spray-Sticker	0.63	0.0a	0.0a
Agri-Dex	2.5	0.0a	0.0a
Agway Target NL	0.63	0.0a	0.0a
Wex	0.78	0.0a	0.0a
Bio-88	0.63	0.0a	0.0a
Bond Spreader-Sticker	2.5	0.0a	1.2b
No adjuvant	-	1.2b	1.2b
No Bayleton	-	56.0c	69.8c

[1]Infection percentages are the average of five 20-tree-replicates determined 9 months after inoculation. Sprays contained 0.6 grams active Bayleton ingredient per liter.

[2]Means followed by a common letter do not differ significantly (P=0.05). Duncan's new Multiple Range Test was used to compare column means and Student's T test was used to compare rainfall effects. Zero percentages were excluded from these analyses.

a seed treatment in Georgia, Arkansas, Virginia, South Carolina, and Florida. All other southern States have not granted approval of this use and nurserymen in these states must await federal or state approval. If seeds germinate over a period of several weeks, repeated spraying appears to be necessary during the emergence period unless seed are treated or sufficient quantities of the fungicide are absorbed by seed sprayed before their germination. A test was therefore, designed in which Bayleton was applied as a spray at intervals during the germination period to seedlings originating from both treated and nontreated seed. The results of this test clearly show that insufficient quantities of Bayleton are absorbed by seed when sprays are applied before germination (table 6).

Incidence of fusiform rust in nurseries having used Bayleton operationally may, therefore, be attributed to: (1) its inability to protect seedlings emerging between any two sprays applied at intervals greater than 7 days; (2) its inability to eradicate infections 14 or more days old; and (3) inadequate coverage of seedling foliage with any spray application. An improved spray schedule is to (a) apply a first spray 7 days after germination begins or no later than 7 days after the first infection period following the beginning of germination; (b) apply a second spray 7 days later or no later than 7 days after the first infection period following the first spray; (c) thereafter, apply two additional sprays during the remaining rust hazard season (until the first week of July) at intervals not to exceed 35 days. Ferbam sprays can be used to help prevent infections where seedlots germinate over an extended period. In States where Bayleton can be used as a seed treatment, the first spray must be applied 14 days after germination begins or no later than 7 days after the first infection period following the first 14 days of seed germination. Thereafter, sprays should be applied at intervals not to exceed 35 days.

Table 3.—Efficacy of Bayleton[1] *is preventing fusiform rust infections in slash pine seedlings originating from Bayleton treated and nontreated seed and inoculated at differing time intervals after seed germination.*

	Seedling galled[2] (percent)	
Seedling age at inoculation (days after emergence)	Untreated checks	Seed treatment only
7	39.0 b	0.0 f
14	49.7 b	4.1 e
21	74.8 a	13.1 de
28	81.7 a	42.3 bc
35	77.7 a	33.7 c
42	79.0 a	62.6 ab
49	82.2 a	53.8 b
56	88.7 a	71.1 a
63	79.1 a	76.7 a
70	86.5 a	70.9 a

[1]Bayleton was formulated in aqueous suspension at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used to soak seed at room temperature for 24 hours.

[2]Infection percentages are the average of five 20-tree replicates determined 10 months after inoculation. In each column, means followed by a common letter are not significantly different (P=0.05). In each row, means underlined are not significantly different (P=0.05) according to Duncan's Multiple Range Test.

In an attempt to determine if operational use of foliar sprays in nurseries are detrimental to the development of mycorrhizae, Bayleton was applied at differing rates and frequencies to slash and loblolly pine seedlings. Roots were examined at the end of the growing season to evaluate mycorrhizal development. Applications of 4, 6 and 8 ounces active ingredient per acre in multiple applications (up to 4) did not harm mycorrhizal development on slash and loblolly pine seedlings (tables 7 and 8). First year data from a study designed to determine if Bayleton accumulates in soil from operational sprays indicate very little effect on mycorrhizal development even

Table 4.—Efficacy of Bayleton[1] in preventing or eradicating fusiform rust infections in slash pine seedlings when foliar sprays are applied (with and without seed treatment) at differing time intervals before and after inoculation with the rust fungus

	Seedlings galled[2] (percent)			
	Sprayed before inoculation		Sprayed after inoculation	
Treatment schedule (days before or after inoculation)	Foliar spray only	Foliar spray and seed treatment	Foliar spray only	Foliar spray and seed treatment
1	- -	- -	0.0a	0.0a
7	0.0a	0.0a	0.0a	0.0a
14	0.0a	0.0a	8.7b	0.0a
21	0.0a	0.0a	20.2c	5.5b
28	0.0a	0.0a	48.9d	28.4c

[1]Bayleton was formulated in aqueous suspensions at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used as foliar sprays and to soak seed for 24 hours at room temperature.

[2]Means followed by a common letter do not differ significantly (P=0.05) according to Duncan's Multiple Range Test. Infection percentages are the average of five 20-tree replicates determined 10 months after inoculation. Untreated checks are 79.0 percent infected which differed significantly from 48.9 percent infection at 28 days.

Table 5.—Aecial sporulation of fusiform rust galls after topical application of two fungicides

Treatment[1] and rate of a.i. (mg/liter)	Year of observation 1977	1978	1979	1980
	Percent			
Benodanil				
0	76 a	94 a	36 a	60 a
150	66 a	56 b	10 a	30 a
300	68 a	55 b	7 b	40 a
600	56 a	46 b	11 b	50 a
Bayleton				
0		75 a	16 a	30 a
500		75 a	15 a	40 a
1000		77 a	10 a	30 a
2000		65 a	13 a	20 a

[1]Benodanil was applied 3/18/77 and Bayleton 10/13/77 at the average rate of 260 ml/gall (runoff) with a paint brush after the outer, rough bark was removed with a gloved hand. Means within each treatment column followed by a common letter do not differ (P=0.05) according to Duncan's Multiple Range Test.

Table 6.—Efficacy of Bayleton[1] in controlling fusiform rust in slash pine seedlings when foliar sprays are applied at intervals during seed germination to seedlings originating from Bayleton treated and nontreated seed

		Seedlings galled[2]		
Treatment schedule (days after seed sown)	Seed germination at treatment date	Untreated checks	Foliar spray only	Foliar spray & seed treatment
	Percent			
7	48.9	82.0 ab	63.3 d	0.0 a
9	62.9	86.0 b	48.1 c	0.0 a
11	72.2	69.8 a	36.1 c	0.0 a
13	83.0	75.4 ab	22.0 b	0.0 a
15	87.9	79.0 ab	15.7 b	0.0 a
21	100.0	77.1 ab	0.0 a	0.0 a

[1]Bayleton was formulated in aqueous suspensions at 0.6 grams active ingredient and 2.5 ml Agri-dex adjuvant per liter and used as foliar sprays and to soak seed at room temperature for 24 hours.

[2]Infection percentages are the average of five 30-48 tree replicates (50 seed sown/replicate) determined 10 months after inoculation. Inoculations were made 30 days after seed were sown. In each column means followed by a common letter are not significantly different (P=0.05) according to Duncan's new Multiple Range Test. All row means not underlined differed (P=0.05) according to Fishers F and Duncan's Multiple Range Test.

when 24 ounces of the active ingredient are applied per acre (table 9).

Bayleton was also tested on 1-0 loblolly nursery stock applied at different rates as a top-dip, root-dip, or as a clay-slurry root-dip to determine if such treatments would provide protection against rust infections during the first year in the plantation. The results of this study show that Bayleton applied in a clay-slurry root dip provides control during the first year after outplanting (table 10).

Table 7.—Effect of field applications of Bayleton on production of short roots with mycorrhizae by slash pine seedlings

Treatment[1]		Rate (kg/ha)	Spray interval	No. of appli-cations	Short roots with mycorrhizae (%)[2]
Control		--	--	--	52.7 a[3]
Bayleton	SS	--	--	--	49.0 a
Bayleton	SS+FS	0.28	2-wk	4	45.4 a
Bayleton	SS+FS	0.28	3-wk	3	49.0 a
Bayleton	SS+FS	0.42	2-wk	4	43.5 a
Bayleton	SS+FS	0.42	3-wk	3	39.2 a
Bayleton	SS+FS	0.56	3-wk	3	43.7 a
Bayleton	SS+FS	0.56	4-wk	2	44.1 a
Bayleton	PPI	0.56	--	1	44.0 a
Bayleton	PPI	1.12	--	1	37.7 a

[1]Abbreviations: SS=seed soak (800 mg Bayleton/l for 24 hr); FS=foliar spray; PPI=preplant soil incorporated.
[2]Each figure represents the average of 10 seedlings from each of 8 replicate plots.
[3]Means followed by the same letter do not differ (P=0.01) according to Duncan's Multiple Range Test.

Table 8.—Effect of field applications of Bayleton on production of short roots with mycorrhizae by loblolly pine seedlings

Treatment[1]		Rate (kg/ha)	Spray interval	No. of appli-cations	Short roots with mycorrhizae (%)[2]
Control		--	--	--	35.4 a[3]
Bayleton	SS	--	--	--	32.1 a
Bayleton	SS+FS	0.28	2-wk	4	32.0 a
Bayleton	SS+FS	0.28	3-wk	3	35.2 a
Bayleton	SS+FS	0.42	2-wk	4	28.5 a
Bayleton	SS+FS	0.42	3-wk	3	35.3 a
Bayleton	SS+FS	0.56	3-wk	3	24.8 a
Bayleton	SS+FS	0.56	4-wk	2	30.4 a
Bayleton	PPI	0.56	--	1	35.9 a
Bayleton	PPI	1.12	--	1	34.3 a

[1]Abbreviations: SS=seed soak (800 mg Bayleton/l for 24 hr); FS=foliar spray; PPI=preplant soil incorporated.
[2]Each figure represents the average of 10 seedlings from each of 8 replicate plots.
[3]Means followed by the same letter do not differ (P=0.01) according to Duncan's Multiple Range Test.

Table 9.—Effect of Bayleton foliar sprays applied to the same seed beds annually on production of mycorrhizal roots by loblolly pine seedlings: first-year-data from MacMillan-Bloedel nursery, 1981-1982

Treatment	No. mycorrhizal roots/ 10 cm of laterals
Control	33.3
Bayleton 1 X*	34.4
Bayleton 2 X	30.6
Bayleton 4 X	28.6

*1 X rate=6 oz. a.i./acre

Table 10.—Efficacy of Bayleton[1] for control of fusiform rust in 1-0 loblolly pine nursery stock when applied at different rates and methods before artificial inoculation 3 months after treatment or exposure to first year natural-field inoculum

Treatment	Bayleton concentration (mg/liter)	Seedlings galled[2] (percent) Greenhouse-artificial inoculations	Nursery-natural infections
Checks	0	10.9 a	4.0 a
Check-clay slurry	0	4.8 a	6.3 a
Top dip	600	0.0 b	4.0 a
	800	0.0 b	4.2 a
	1,000	0.0 b	2.1 b
	1,500	0.0 b	0.0 c
Root dip	600	0.0 b	2.0 b
	800	0.0 b	4.2 a
	1,000	0.0 b	2.0 b
	1,500	0.0 b	0.0 c
Clay-slurry	600	0.0 b	0.0 c
	800	0.0 b	0.0 c
	1,000	0.0 b	0.0 c
	1,500	0.0 b	0.0 c

[1]Bayleton was formulated to contain 2.5 ml of the adjuvant, Agri-dex, per liter. The clay-slurry contained 45.35 percent kaolinitic clay (weight/volume).
[2]In each column, means followed by a common letter do not differ (P=0.05) according to Duncan's Multiple Range Test.

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RECOMMENDED BAYLETON® TREATMENTS FOR CONTROL OF FUSIFORM RUST IN FOREST TREE NURSERIES

W. D. Kelley[1/]

These recommendations are based on results of tests conducted annually since 1978 in both nurseries and greenhouses. They reflect the most effective and economical means of controlling fusiform rust in forest tree nurseries, while simultaneously producing minimal effects on mycorrhizal fungi and other non-target organisms.

It is essential that seed treatment with Bayleton® be included in the rust control procedures in order to obtain maximum protection. Seed treatment provides protection from rust throughout the seedling emergence period; a foliar spray with Bayleton® protects only the seedlings that are emerged when the spray is applied. Seedlings that emerge after the spray are not protected from rust until he next Bayleton® spray.

I. Seed Treatment. - Seed may be treated with Bayleton® using either the seed soak procedure (see "A" below) or the seed dressing procedure (see "B" below). The seed soak procedure is labelled for use (24-C) in all southern states except Louisiana; the seed dressing procedure is labelled for use (24-C) only in Alabama. A federal (EPA) label permitting the use of the seed dressing procedure is pending.

A. Seed Soak

- Use of Bayleton® (triadimefon) seed soak treatment at a dosage rate of 1 oz of Bayleton 50 WP per 5 gallons of water.
- Soak loblolly or slash pine seed in the above solution for 24 hours at room temperature, stirring occasionally.
- Additional seed treatments (e.g., Arasan or Anthraquinone) may be applied following the Bayleton® seed soak and partial drying.

1/Associate Professor, Botany, Plant Pathology and Microbiology Department, Alabama Agricultural Experiment Station, Auburn University, AL 36849.

- Treated seed may be held under refrigeration for at least 26 days after soaking without affecting efficacy of Bayleton•.

B. Seed Dressing

- Use Bayleton• (triadimefon) at a dosage rate of 1 oz of Bayleton• 50 WP per 25 lb of seed.
- Apply the Bayleton• powder to wetted (water or latex solution) pine seed in a tumbler apparatus and tumble for 10 minutes.
- Additional seed treatments (e.g., Arasan or Anthraquinone) may be applied following the Bayleton• treatment.
- Treated seed may be held under refrigeration for at least 26 days after treatment without affecting efficacy of Bayleton•.

II. Foliar Sprays. - This foliar spray regime assumes seed treatment with Bayleton• is used. Bayleton• foliar sprays may be applied with any suitable spray rig properly calibrated to deliver between 30 and 75 gallons per acre and equipped with hollow cone nozzles.

- Use three (no more than four) Bayleton• foliar sprays, each at a dosage rate of 4 oz ai (8 oz of Bayleton• 50 WP) per acre. Each acre volume of spray mixture also should contain 4 oz of Agri-dex• oil-surfactant blend.
- Apply the first foliar spray 26 ± 2 days after sowing.
- Apply the second foliar spray 21 days after the first spray.
- Apply the third foliar spray 21 days after the second spray or between June 7 and 10, whichever is earlier.
- A Bayleton• foliar spray applied between June 7 and 10 will provide adequate protection from fusiform rust until the end of the spore flight period.
- Nurserymen who chose to use four foliar sprays (usually unnecessary) should shorten the interval between sprays to 14 days.

Bayleton• is available from Woolfolk Chemical Works, Inc., P.O. Box 938, Fort Valley, GA 31030 - (912-825-5511) and other distributors of Mobay Chemicals, and Agri-dex• is available from Helena Chemical Co., Suite 3200, 5100 Poplar, Memphis, TN 38137 (901-761-0050) and other distributors of Helena Chemicals.