Chapter 20

Insect and Disease Management

Wayne N. Dixon, Edward L. Barnard, Carl W. Fatzinger, and Thomas Miller

Abstract

Insect and disease management is essential for successful regeneration of pines in the southern U.S. Because of the demands imposed by intensive culturing of southern pines, land managers must have a broad working knowledge of entomology and pathology so they can recognize, assess, and remedy many types of insect and disease problems in seed orchards, nurseries, and the field. In seed orchards, insects pose the largest threat to seeds and cones; in nurseries, diseases are the major pest problems; in the field, insects and diseases prevail equally. Regardless of the regeneration management unit, the interactions among insects, diseases, and their hosts must not be overlooked. No control may be warranted when damage is limited to a small part of a single tree; however, various treatments may be necessary when entire seed crops, seedbeds, or plantations are invaded. Wherever possible, preventive measures should be preferred to reactionary treatment because prevention is generally more efficacious. Although pesticides are available for most pests, alternative means — cultural, physical, or biological — should be investigated. In response to heightened environmental awareness, integrated pest management, a holistic approach to solving pest problems, is receiving considerable attention in forestry.

20.1 Introduction

Insects and diseases are natural components in the southern pine ecosystem. Their presence there is vital to the recycling of energy and nutrients; however, many of these same insects and diseases become pests when they interfere with pine regeneration or growth.

The successful regeneration of southern pines is highly dependent on management of insects and diseases from the time of establishing seed-orchard stock, through flower pollination and cone maturation in a seed-orchard, during germination and over the year of intensive cultivation in a nursery, and through the first few years after outplanting in the field. Investments in a pest management program can increase yields of viable seed-orchard seed and high-quality nursery seedlings from nurseries and improve survival and growth of seedlings in the newly planted stand.

The objectives of this chapter are to identify and discuss common insect and disease pests which can affect pine regeneration in the southern U. S. More than 80 industry, state, and federal nurseries in the South produce over 1 billion seedlings annually [67]. We describe the life histories of the pests in detailed appendices (see Appendices A20.1, A20.2, and A 20.3, this chapter) and present approaches for managers to use in evaluating pest problems, determining the need for control (chemical, cultural, physical, biological), and effectively applying the appropriate strategies.

20.2 Potential Damage from Pests

The management of pest populations and damage is a necessity; otherwise, the economic losses (expressed as dollars, breeding stock, seed, or seedlings) can be enormous. The extent of pest damage depends on many factors including weather, host susceptibility, pest virulence, natural controls, site variables, and pest control measures taken. The current practice of culturing large numbers of closely related pines of a single species in limited growing areas exacerbates the potential for pest incidence and damage. At minimum, damage may involve an injured branch tip, flower, root, or other small component of an individual tree. No control is warranted in such instances. At worst, entire clones [43], seed crops [139], seedbeds [132], or plantations [111] can be lost or severely damaged in the absence of pest management programs. Between these two extremes — no control and hopeless, reactionary responses — exists a middleground wherein some losses occur, but at economically acceptable levels.

In seed orchards, seed may be lost from the time the female strobilus, or seed-bearing cone, is formed until cones mature 18 to 22 months later (Fig. 20.1). For the majority of the southern pines, most strobili are lost during

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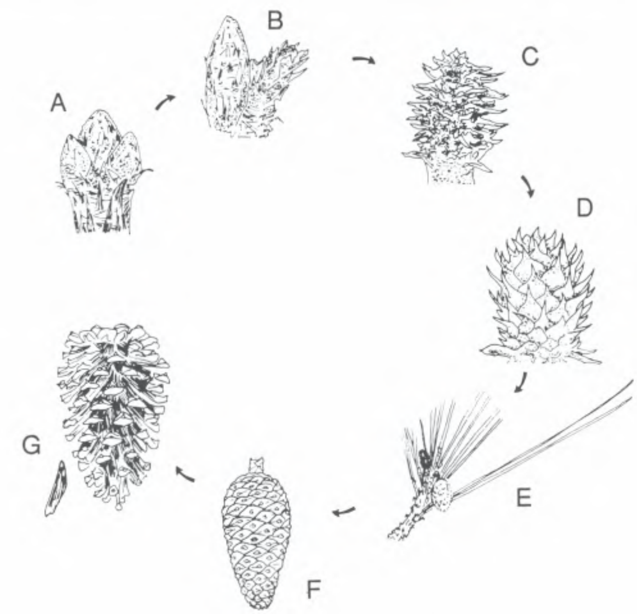

Figure 20.1. Developmental stages of the female strobilus for slash pine. Flowers and cones not drawn to scale. (A) Female strobilus small, enclosed within bud scales. Vegetative shoot in middle. First year, January—March (0 months). (B) Female flower (pink, red, or light green) emerging through top of scales. (C) Flower completely emerged, maximally receptive to pollen. Flower scales are nearly at right angle with axis of conelet. **(D)** Flower no longer receptive to pollen. Scales swollen and upright. First year, March (3 months). (E) Conelet or first year cone; March of first year to June of second year (14 months). (F) Second year cone; June—September. Green cone stage. (G) Mature open cone and seed. Second year cone; September—October (18-22 months).

the first year of development. In the first year, loss of female flowers, largely due to insects (70 to 90%), may range from 33 to 60%; in the second year, loss of cones, largely due to coneworms *(Dioryctria* spp.), may be as great as 78%. A survey of five species of southern pine in seed orchards, conducted from 1973 to 1976, revealed that strobilus losses were highly variable among years, orchards, and clones. In the absence of pest management, insects destroyed from 2 to *77%* of the cone crops of loblolly *(Pious taeda* L.), longleaf *(Pious palustris* Mill.), shortleaf *(Pious echinata* Mill.), slash *(Pious elliottii* Engelm.), and Virginia *(Pious virginiana* Mill.) pines from the time female strobili first appeared as flowers throughout their 18- to 20-month period of development [63]. Seed orchards can also lose entire trees to pests. For example, 58 of 66 ramets of one clone (valued at $116,000) were killed by bark beetles [southern pine engraver, *Ips grandicollis* (Eichh.), six-spined engraver, *I. calligraphic* (Germ.)] and twig beetles *(Pityophthorus* spp.) [43].

In nurseries, diseases are the major pest problems generally encountered. The impact of a single disease on a nursery crop can be devastating. For example, charcoal root rot [caused by *Macrophomina phaseolina* (Tassi) Goid.] was associated with the loss of 16.5 million seedlings (valued at $148,000) in one southern nursery in 1976 [132].

In field outplantings, insects and diseases are equally prevalent as pest problems. Fusiform rust *[Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme],* brown-spot needle blight *[Mycrosphaerella dearnessii* Barr *(=Scirrhia acicola* [Deam.] Siggers], and other diseases (dependent on host species and geographic location) can cause significant field losses, as can reproduction weevils [pales weevil, *Hylobius pales* (Herbst); pitch-eating weevil, *Pachylobius picivorus* (Germar)], pine tip moths *(Rhyacionia* spp.), and pine sawflies *(Neodiprion* spp.) [8, 75].

20.3 Integrated Pest Management

Pesticides have been the major tool of pest control over the past 3 decades. The high risk of severe insect damage in seed orchards has led to near compulsory insecticide spray programs; several insecticides are registered for suppression of cone and seed insects. Annual control costs may range up to about $495/ha. Important variables that bear on chemical suppression are insecticide used, frequency of application, and costs of labor, equipment, and fuel [66]. Soil fumigation of nursery beds, a control technique that may cost from $1,235 to 2,223/ha, is a virtual certainty because of the high risk of damping-off *(Pythium* spp., *Phytophthora* spp., *Rhi:octonia* spp., *Fusarium* spp., *M. phaseolina,* and other spp.) and other root diseases in nurseries. A fungicidal seed soak and two or three foliar applications are necessary to effectively suppress fusiform rust in nurseries [84].

In the late 1960s, however, pest-control strategies started to shift away from total dependence on chemicals to programs including other types of tools and strategies. Pest management, in general, has undergone a rapid evolution both in terms of technology and philosophy in recent years. Pest control, pest management, and — most typically now, integrated pest management (IPM) [135] — are common labels for the different approaches to regulating pest populations and associated damages.

IPM has been defined numerous times in the literature. According to Waters [140], it is "the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially acceptable. It is implicit that the actions taken are fully integrated into the total resource management process — in both planning and operation. Pest management, therefore, must be geared to the life span of the tree crop as a minimum and to a longer time span where the resource planning horizon so requires."

As the concept of IPM has matured, more restrictive versions, based on the resource or crop being managed, have been offered. Coulson and Witter [28] defined integrated forest pest management (IFPM) as a conceptual methodology for achieving forest-protection goals in light of multiple forest values. IFPM considers the pests, the strategies and tactics of pest management, and the silvicultural manipulation of the tree species of interest. Coulson and Witter [28] propose (1) that "integration" implies consideration of multiple insect and disease pests because problems are often the result of the combined action of several pests, (2), that an individual disease or insect may be the specific cause of a problem, but actions taken against that pest should not aggravate another pest problem, and (3) that pest-management recommendations must be integrated in time so that current activities do not worsen a future problem. "Pest management" also implies that the actions taken result in a positive cost-benefit ratio. Although usually thought of as a monetary return on investment, such benefits might be measured in terms of aesthetics, recreation, wildlife, or water quantity or quality. Filer and Cordell [67] defined integrated nursery pest managemagent (INPM) as the reduction of pest problems in the nursery through a coordinated pest-management program. To be successful, INPM requires a systematic approach from integrating such related disciplines as soil science, silviculture, forest pathology, entomology, and weed science. Emphasis must be placed on preventing, containing, and excluding pests.

Current intensive forest management can no longer tolerate a reactive approach to pest outbreaks, but instead must combine careful planning with good silviculture [16]. Therefore, in this chapter we emphasize an IPM (IFPM and INPM) approach to pest problems, in which chemical, cultural, physical, and biological measures, singly and in combination, are considered.

20.4 Problem Assessment

Assessing pest problems may be difficult for several reasons. First, we will discuss pests according to the regeneration management unit — seed orchard, nursery, or field — affected by the disease or insect; however, there is a danger of incorrectly identifying the actual initiation point of the pest problem because of the management labels used. For example, a pathogen such as the pitch canker fungus [*Fusarium subglutinans* (Wollenw. & Reink.) Nelson, Toussoun and Marasas comb. nov.] may infect seeds in cones, but the resulting disease may not be expressed until the infected seedlings are outplanted (Fig. 20.2). Typically, a forest manager will only treat the field problem and not realize its true origin. A better response would be to address the problem at its origin in the seed orchard to minimize or prevent production of contaminated seedlots. The post-outplant manifestation of symptoms is referred to

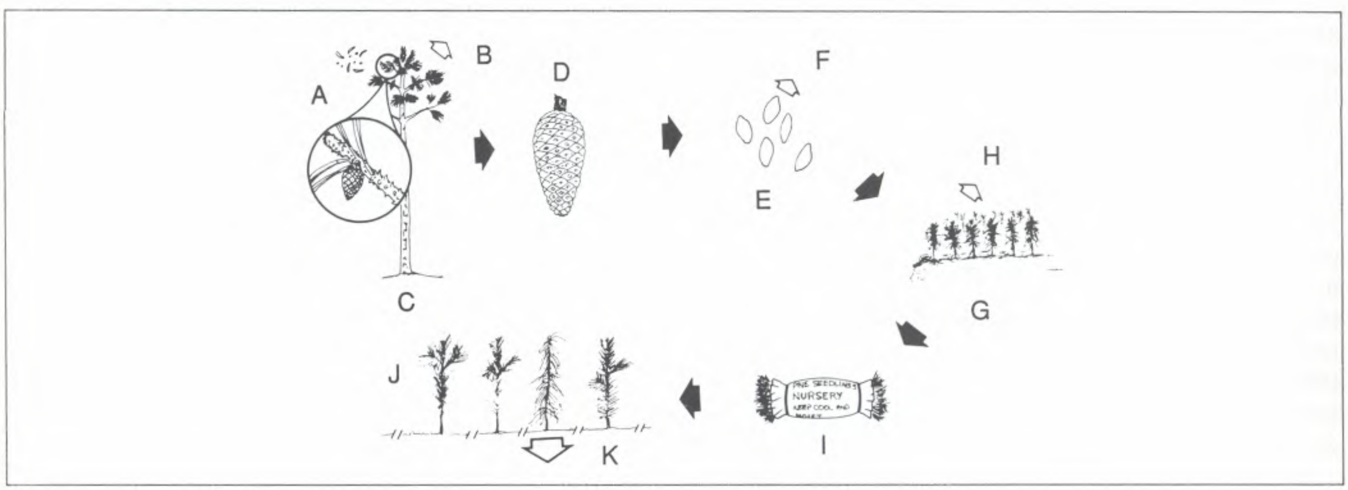

Figure 20.2. Conceptualized route of the pitch canker fungus in the regeneration continuum of southern pines. **(A)** *Fusarium subglutinans* spores. (B) Loss from aborted cones. (C) Seed orchard tree. **(D)** Symptomless, infected cone. (E) Infected seed. (F) Loss from nonviable seeds, expressed in germination. (G) Infected seedlings in nursery. (H) Loss from dead seedlings. (I) Symptomless, infected seedlings. **(J)** Seedlings in field. (K) Latent disease development; loss from dead seedlings.

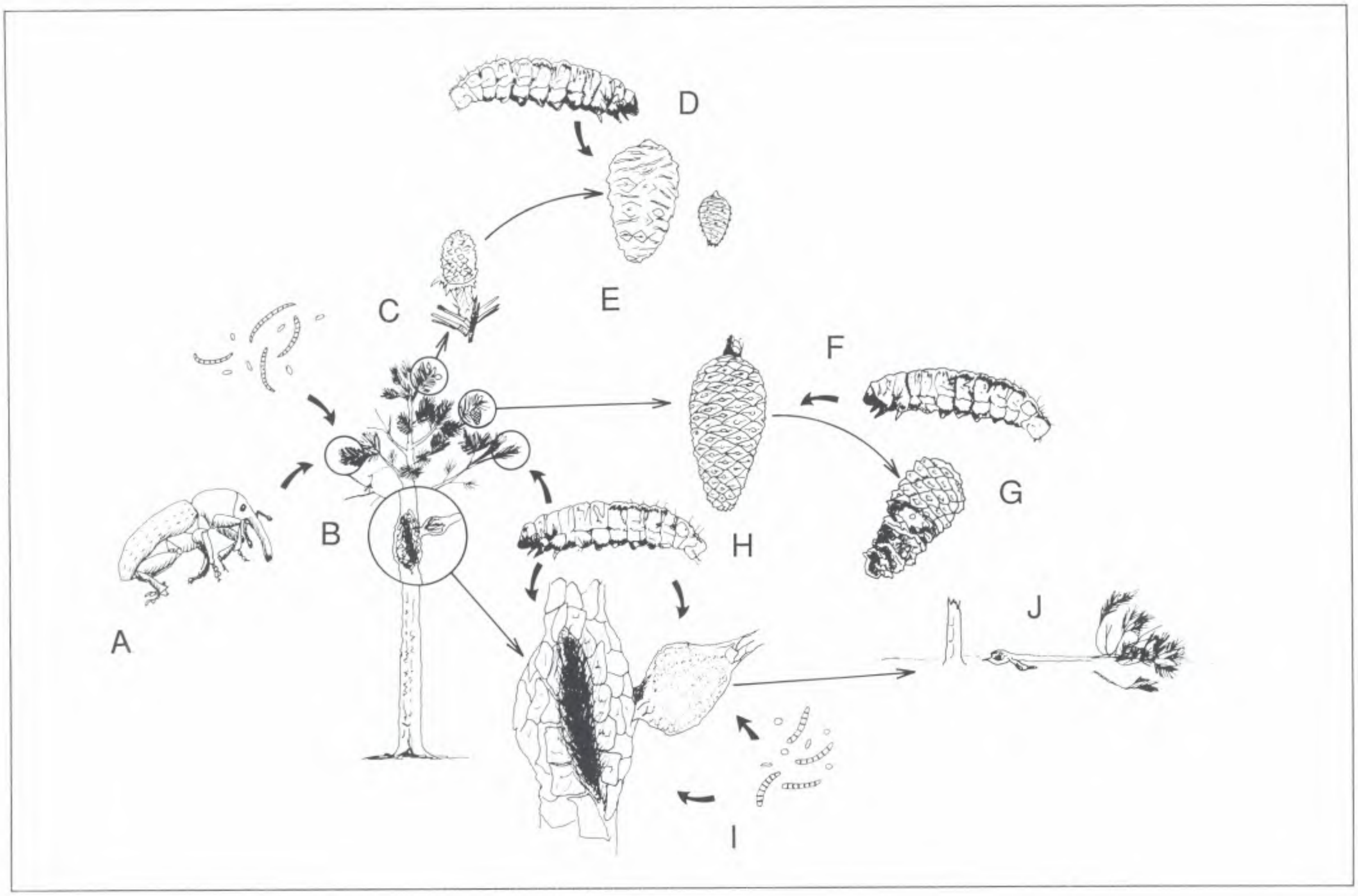

Figure 20.3. Some key interactions between insects and diseases affecting regeneration of southern pines. (A) Eastern pine weevils feed on tender shoots (late summer and fall); create wounds. (B) Wounds infected by spores of pitch canker fungus, windblown or carried by feeding weevils (late summer and fall). (C) Flowers (strobili) infected by spores of cone rust fungus (mid to late winter). (D) Coneworms infest diseased conelets (early to late spring). (E) Infected conelets increase 2 to 4 times in size; produce aeciospores (mid to late spring); die and fall from tree. (F) Coneworms, populations now greatly expanded, migrate from diseased cones, infest healthy 2nd year cones. (G) Infested cones die or are damaged and produce fewer seeds. **(H)** Coneworms feed on rust galls year-round. Female moths deposit eggs; larvae attack galls, complete development. **(I)** Spores of pitch canker fungus may infect wounds made by coneworms in rust galls. (J) Rust galls (with or without pitch canker infection) may kill tree directly or indirectly (through breakage at structurally weakened gall).

as latent symptom or disease development. Although not a substantive problem in most cases, latent development should not be overlooked when evaluating diseases which manifest themselves early in the life of newly established plantations. By the same token, the possibility of infected or contaminated seed should be considered when evaluating nursery diseases. The actual point of pathogen infection or insect infestation must be determined to allow efficient management strategies to be formulated. Misidentification in problem assessments can be minimized if we recognize regeneration management units as a growth continuum (seed orchard = flower, conelet, cone, seed; nursery = seed, seedling; field = juvenile, mature seedling), rather than as discrete and unconnected phases.

Second, the interaction of insects and diseases can complicate pest management. Galls caused by fusiform rust are frequently attacked by coneworms. The wounds produced by coneworm activity may then be infected by the pitch canker fungus. The combined damage may either kill the tree or break stems and branches at the gall (Fig. 20.3). A destructive interaction also exists between southern cone rust *(Cronartium strobilinum* Hedgc. & Hahn) and coneworms. Strobili infected by cone rust provide a favored habitat for the buildup of coneworm larvae [e.g., south coastal coneworm, *Dioryctria ebeli* Mutuura and Munroe] which then attack healthy second-year cones on the same branches. This disease-insect interaction results in greater cone and seed losses than does either of the pests independently. Another known interaction exists between the pitch canker fungus and the eastern pine weevil, *Pissodes nemorensis* Germar; and similar interactions are suspected between pitch canker and pine tip moths, seed bugs [southern pine seed bug, *Leptoglossus corculus* (Say), and shieldbacked pine seed bug, *Tetyra bipunctata* (Herrich-Schaffer)], and pine needle midges *(Contarinia* spp.).

Finally, the processes of management themselves may cause or contribute to a pest problem. Seed orchards and

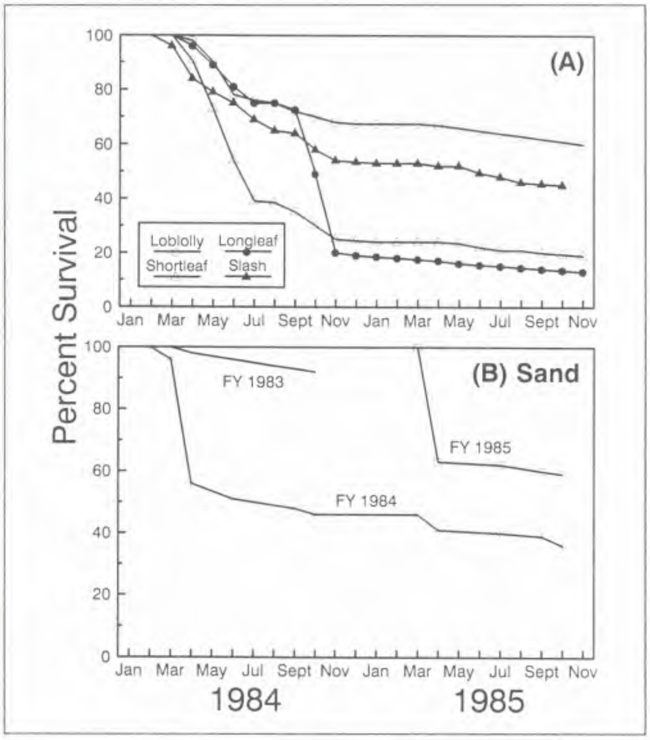

Figure 20.4. Survival curves for female strobili of five species of southern pines: (A) Loblolly, longleaf, shortleaf, slash [63] and (B) sand [*Pinus clausa* (Chapm. ex Engelm.) Vasey ex Sarg.] [Fatzinger and Ebel, unpublished data].

nurseries require intensive cultural practices to insure maximum productivity. In seed orchards, improper mowing, tree shaking, and cone collecting all may create wounds that will serve as infection courts or attractive sources to insects. In nurseries, control practices can increase insect attacks or disease development if applied improperly. In a plantation, thinning operations can result in bark beetle and wood borer infestations. Mistakes in the timing, rates, and application of fertilizers and pesticides may predispose seed orchard, nursery, and field trees to attacks by pests.

In diagnosing problems, managers must look at the whole picture — diseases, insects, and cultural practices. No one factor should be considered independently of the others. A single agent may be responsible, but all other possible causes and interactions should be examined both in diagnosis and treatment.

20.5 Pest Problems and Control Strategies in Seed Orchards

20.5.1 Insects

Seven orders of insects directly affect the production of cones and seeds in southern orchards: Coleoptera (cone beetles, May beetles, reproduction weevils, and pine sawyer beetles), Diptera (cone midges), Hemiptera (seed bugs), Homoptera (scales), Hymenoptera (sawflies and seed chalcids), Lepidoptera (coneborers, coneworms, seedworms, tip moths, and loopers), and Thysanoptera (thrips) (see Appendices A20.1, A20.1 and A20.2, this chapter). As noted earlier, female strobili and developing seed are subject to attack by insects throughout their development, especially during the first year but continuing at a decreased rate until cones mature (Fig. 20.4). In the more mature strobilus, covert damage by insects that feed directly on seed developing within cones may be observed only on radiographs of mature seed [33] and cannot be directly assessed in the field.

20.5.1.1 Identifying damage in the seed orchard

Generally, insect pests are not directly observed in a seed orchard. Instead, orchard managers are much more likely to see signs of insect damage on or in strobili due, in part, to insects' seasonal distributions (low to high densities over the year), feeding habits (hidden within a cone, branch, or bud), coloration (camouflage), nocturnal behavior (of some), and small size. In many cases, the type of strobilus damage helps identify the species of insects responsible.

Several insect species feed externally on female strobili and partially or completely devour flowers or conelets during late winter and early spring. These signs of damage are similar for the pine conelet looper [*Nepytia semiclusaria* (Walker)], the Virginia pine sawfly [*Neodiprion pratti pratti* (Dyar)], pales weevil, pitch-eating weevil, May beetles (*Phyllophaga* and *Polyphylla* spp.), and pine sawyer beetles (*Monochamus* spp.). The slash pine flower thrips [*Gnophothrips fuscus* (Morgan)] also feeds externally on the young flowers of slash pine, but the signs of damage initially consist of small beads of resin covering feeding wounds; flowers die or strobili deform because of asymmetrical growth of scales later on.

Varying degrees of injury are caused by insects that feed internally on the developing strobili. Coneworms and coneborers (*Eucosma* spp.) often destroy the interior of cones, leaving only the outer surface packed with frass. Entrance holes and additional frass are generally present on the cone surface. Three species of coneborers and five species of coneworms are of primary importance in the South: the shortleaf pine cone borer (*Eucosma cocana* Kearfott), the white pine cone borer (*E. tocullionana* Heinrich), the southern pine coneworm [*Dioryctria amatella* (Hulst)], blister coneworm [*D. clarioralis* (Walker)], webbing coneworm (*D. disclusa* Heinrich), south coastal coneworm (*D. ebeli* Mutuura & Munroe), and the loblolly pine coneworm (*D. merkeli* Mutuura & Munroe). Larvae of the Nantucket pine tip moth [*Rhyacionia frustana* (Comstock)] bore into and kill strobili, buds, and shoots of seed-orchard trees. The white pine cone beetle [*Conophthorus coniperda* (Schwarz)] feeds internally at the base and stalk of eastern white pine (*Pinus strohus* L.) cones. Female strobili of southern pines also are infested internally by midges, including the southern cone gall midge (*Cecidomyia bisetosa* Gagne), the cone resin midge (*Asynapta hopkinsi* Felt), and *Resseliella Silvana* (Felt).

Two species of Hemiptera affect seed production in southern pine seed orchards. The southern pine seed bug feeds on the ovules and seed of southern pines, and nymphal (immature stage of development) feeding causes conelets to abort [37]. The shieldbacked pine seed bug feeds on the developing seeds in second-year strobili and possibly also on shoots. Larvae of three species of seedworms, the slash pine seedworm *(Cydia anaranjada* Miller), the longleaf pine seedworm *(C. ingens* Heinrich), and the eastern pine seedworm *[C. toreuta* (Grote)], feed internally on seeds of southern pines.

20.5.1.2 Management strategies in the seed orchard

More than 4,050 ha of pine seed orchards exist in the southeastern United States. This area is a relatively small proportion of that currently devoted to pulp and timber production. The orchards are intensively managed for maximum production of cones and seed and may therefore concentrate populations of destructive insects because of abundance of suitable habitat (strobili and seed). Moreover, pine seed orchards are commonly surrounded by vast pine stands which also serve as additional habitat for the complex of insects that collectively damage or destroy strobili and seed throughout much of the year. Most of the insects are highly mobile and probably are capable of reinfesting an orchard in a short time. The overlapping life cycles and generations of cone and seed insects also must be considered when developing management strategies for orchards.

The gains from a well-developed insect control program can be substantial. Fatzinger et al. [66] reported on strobilus survival and yields of viable seed from two differently managed loblolly pine seed orchards growing on similar sites and about 5 km apart in South Carolina. One orchard had been untreated other than two mowings a year for at least 8 years; the other had been treated for several years with insecticides, fertilizers, and other cultural practices (e.g., mowing five times/year, subsoiling, and pruning or thinning). The treated seed orchard yielded about twice as many mature cones with nearly 3 times as many viable seed per cone as did the untreated orchard.

Management strategies for cone and seed insects are currently limited to either repeated applications of insecticides during spring and summer, or a single application of a systemic insecticide with a relatively long residual toxicity during late winter, or a combination of both. During spring and summer, a series of insecticide applications are effective for reducing losses on both the first- and second-year female strobili, which are present on trees concurrently. This management strategy is largely dictated by the lack of adequate systems for predicting levels of insect damage, by the potential for reinfestation of insects in treated orchards once the residual toxicity of an insecticide has diminished, and the overlapping seasonal distributions of destructive insects. Aerial applications of pesticides are replacing ground applications (by hydraulic sprayers, air-blast sprayers, or mist blowers); use of aircraft (fixed wing, helicopter) has facilitated the proper timing of insecticide applications to entire orchards during the relatively short periods when insecticides are most effective.

The physical location of an orchard is another important consideration in developing a pest management strategy. Pesticides generally cannot be used in orchards located close to populated areas or where spray may accidentally drift or toxic residues runoff in water. Ideally, orchards should be established in relatively remote sites some distance from residential, business, or recreational areas and not near lakes, rivers, streams, or habitats of endangered species.

IPM strategies are being developed for southern pine seed orchards. Although pesticides apparently will be an integral part of pest management in seed orchards for some time to come [34], the development of IPM systems should ultimately reduce reliance on these chemicals.

IPM systems include methods for monitoring and surveying cone crops [24, 61, 63] throughout their 18- to 22-month period of development (see Fig. 20.1) in individual orchards. These methods provide periodic estimates of the numbers of cones present within an orchard, projected yields of cones and seed at harvest, identification of biotic and abiotic factors responsible for reduced yields and the amounts of damage caused by each factor, times of year when losses occur, and trends in orchard productivity over time. Partial or complete life tables, useful for quantifying damage caused by different seed-orchard pests [35], also can be constructed with survey data. In particular, the Bramlett-Godbee [24] system quantifies the potential seed production of an orchard and evaluates the impact of cone and seed losses based on periodic observations (six over 2 years). The Fatzinger et al. [61, 63, 64] system quantifies the causes of losses (pest and abiotic) over the period of strobilus development from flowers to mature cones and seed extraction (six to 12 over 2 years). Either of these systems, or a similar one, will increase the effectiveness and cost efficiency of both seed-orchard and pest management and provide a means for evaluating of specific orchard-management practices.

Biological control with light traps and traps baited with sex pheromones has been found useful for monitoring population densities of several species of destructive Lepidoptera. Methods employing sex pheromone traps and degree-day models (based on the principle that growth and development rates of many organisms are dependent on temperature) have been developed for properly timing applications of insecticides to control the Nantucket pine tip moth [70, 71] and are being developed for several species of coneworms for which synthetic sex pheromones are now available [74, 141]. Currently, catches from pheromone traps are used to optimize timing of insecticide applications. However, considerably more research is necessary before these traps can indicate when an economic threshold has been passed, i.e., when the cost of a control treatment is less than the cost of damage from unmanaged insects. A method for sampling insects within the whole crown area of orchard trees is being formulated [144] and research conducted to construct a host-tree developmental curve that will predict the optimum time to apply insecticide to control the slash pine flower thrips [62]. Differences in infestation by cone and seed insects related to clonal variation in slash pine [38] and clonal variation in susceptibility to coneworms in loblolly pine seed orchards have been demonstrated. Selection against susceptible clones or carefully tailored insecticide treatments may reduce a cone or seed insect problem or minimize the need for orchard-wide insecticide treatment [9].

20.5.2 Diseases

Several diseases in southern pine seed orchards periodically cause significant damage and seed losses (see Appendix A20.3, this chapter). Unlike the cone and seed insects that invade most seed orchards annually across the South, diseases are typically more sporadic and localized. For example, southern cone rust occurs only where slash and longleaf pines grow close to evergreen oaks *(Quercus* spp.), and its incidence is high only periodically. Pitch canker occurs as a vegetative disease (i.e., affects only vegetative tissues) in most slash pine seed orchards, but its incidence is highly variable. In loblolly pine seed orchards, pitch canker may be severe for 1 or 2 years, then largely disappear. As a cone and seed disease, pitch canker is also quite variable in its incidence and severity from year to year.

Several root diseases have the potential for causing decline and mortality of trees in southern pine seed orchards, including annosus root rot, caused by *Heterohasidion annosum* (Fr.) Bref., and root diseases caused by *Phytophthora cinnamomi* Rands and *Verticicladiella procera* Kendrick. These pathogens may be present in a root system without revealing themselves through above ground symptoms for several years. The most common symptoms are a general decline in tree vigor, i.e., crown thinning and shortened needle length, followed by death. These diseases are generally diagnosed by excavation of the root systems and collecting samples for laboratory diagnosis.

Several pest interactions also can be important in pine seed orchards (see Fig. 20.3). Cones of slash and longleaf pines affected by southern cone rust provide favorable breeding sites for coneworms *(Dioryctria* spp.) The resulting increased populations of coneworm larvae then attack healthy cones and intensify the cone and seed losses [102]. Fusiform rust galls are frequently attacked by coneworm larvae and the pitch canker fungus, which can then increase the likelihood of stem breakage and tree mortality [52].

20.6 Pest Problems and Control Strategies in Nurseries and Field (0 to 5 years)

20.6.1 Insects

The reforestation of pines by mass production of seedlings in nurseries followed by outplanting or direct seeding in the field is established forestry practice. Insect and mite pests are infrequent to common problems in nursery beds and in the field (see Appendix A20.2, this chapter). Their attacks on seedlings and saplings, resulting in defoliation, chlorosis of needles, girdling of stems, and destruction of roots, can reduce growth and vigor, or kill trees outright [47]. Such losses can be significant.

20.6.1.1 Identifying damage in the nursery and field

Damaged seedlings, rather than the pest itself, are usually the first sign of a pest problem. Some pests are cryptic (remain hidden) or leave the host before symptoms are evident. Although pest specimens are not always essential, managers make the best decisions when the pest is collected and identified. The feeding damage caused by one or more species of insects or mites is often sufficiently unique to identify the pest. To facilitate the identification process, we use four damage groups — sucking insects and mites, defoliating insects, bark and stem feeders, and root feeders — although some insects may be classified in more than one group. Sucking insects and mites damage seedlings by removing fluids from cells. Common signs of their activity are needle discoloration, wilting, or curling, and appearance of sooty mold on foliage. Defoliating insects damage seedlings by consuming foliage. Common signs of their activity are foliage discoloration and loss. Bark and stem feeders damage seedlings by removing outer bark and cambial tissues. Common signs of their activity are foliage discoloration, loss of shoot tips, small to large patches of missing bark, crystallized pitch on stems, partial to complete girdling above or below groundline, and/or toppling of the seedling. Root feeders consume roots and sometimes foliage. Common signs of their activity are foliage discoloration, partial to complete root pruning, root-collar girdling, and/or toppling of the seedling [47].

Sucking insects and mites. — Spider mites [spruce mite, *Oligonychus ununguis* (Jacobi); southern red mite, *0. milleri* (McGregor); twospotted spider mite, *Tetranychus urticae* Koch; and others] are generally a problem in nurseries from late summer through late fall when droughty conditions prevail; they are rarely a problem in the field. Excessive use of pesticides can exacerbate a phytophagous spider-mite infestation through the development of pesticide resistance. Scale insects [pine scale, *Chionapsis heterophyllae* (Cooley); pine needle scale, *C. pinifoliae* (Fitch); pine tortoise scale, *Toumeyella parvicornis* (Cockerell); striped pine scale, *T. pini* (King); Virginia pine scale, *T. virginiana* (Williams & Kosztarab)] are rarely a significant problem. Warm, dry weather and excessive use of certain pesticides promote scale insect outbreaks. Aphids [white pine aphid, *Cinara strobi* (Fitch); *C. pinea* (Mordwilko); Carolina conifer aphid, *C. atlantica* (Wilson); *C. taeda* Tissot; *C. watsoni* Tissot; *C. inivora* (Wilson); *C. pergandei* (Wilson)] are generally not a significant problem in nurseries or the field, but large areas of damage may appear almost overnight. Southwide infestations of *Cinara* spp. were observed on slash and loblolly pine seedlings during the springs of 1988 and 1989. Fire ants (red imported fire ant, *Solenopsis invicta* Buren; other *Solenopsis* spp.), also in abundance, protected the aphids from natural enemies. The tarnished plant bug, *Lygus lineolaris* (Palisot de Beauvois), and possibly other *Lygus* spp. have been implicated as the cause of bushy-top (multiple forks) in loblolly pine, slash pine, and Choctawhatchee sand pine [*Pinus clausa* (Chapm. ex Engelm.) Vasey ex Sarg.] Bushy-top, a recent problem in southern forest nurseries, was first reported from the Northwest. Incidence of bushy-top in a southern forest nursery may range from none to nearly 86% [46, 125, 137].

Defoliating insects. — The pine webworm (*Tetralopha robustella* Zeller) defoliates pine seedlings throughout the South and can kill seedlings < 2 years old. The larvae initially mine needles and later construct nests of silk and frass in which they feed and rest [78]. The pine webworm is commonly encountered in outplantings, but is infrequently observed in nurseries. The redheaded pine sawfly [*Neodiprion lecontei* (Fitch)] is one of the most important native forest insects that defoliate young hard pines [18]. Most nursery infestations are small, localized spots. Field infestations of the pine chafer (*Anomala oblivia* Horn) and pine colapsis (*Colapsis pini* Barber) are sporadic but when present are spectacular. The Texas leafcutting ant [*Atta texana* (Buckley)] is an important pest of pine seedlings in eastern Texas and west-central Louisiana; injury to seedlings is particularly severe during winter when there are few other host plants [51].

Bark and stem feeders. — Newly planted seedlings are highly susceptible to attack by the pales weevil and pitch-eating weevils. The adult weevils are attracted to recent logging operations, site-prepared areas containing fresh pine debris, or areas with recently dead or dying trees and may threaten seedlings planted nearby. Damage is severe enough that seedlings often must be replanted [111]. Seedlings may be debarked exclusively belowground, aboveground, or a combination. The Nantucket pine tip moth, the pitch pine tip moth [*Rhyacionia rigidana* (Fernald)], and the subtropical pine tip moth (*Rhyacionia subtropica* Miller) frequently cause growth loss and deformation by feeding on the buds and shoots of young pines. Significant damage can occur on loblolly, shortleaf, and slash pines.

Root feeders. — White grubs (*Polyphylla* and *Phyllophaga* spp.), mole crickets [northern mole cricket, *Neocurtilla hexadactyla* (Perty); short-winged mole cricket, *Scapteriscus abbreviatus* Scudder; southern mole cricket, *S. acletus* Rehn and Hebard; tawny mole cricket, *S. vicinus* Scudder) [130]], armyworms [southern armyworm, *Spodoptera eridania* (Cramer); armyworm, *Pseudaletia unipuncta* (Haworth); tufted white pine caterpillar, *Panthea furcilla* (Packard); and others], and cutworms [variegated cutworm, *Peridroma saucia* (Hubner), and others] are common nursery pests; they are infrequently to rarely pests in the field. The presence of dense sod, cover crops, and vegetable crops in or near the nursery raises the risk of seedling loss to any or all of these pests [51]. In the field, certain pests have become more prominent where agricultural cropland has been converted to pine-forested land [45]. White grubs and white-fringed beetles, *Graphognathus* spp., can be abundant under agricultural crops or weeds in fallow years. Pine seedlings established on these converted lands can sustain severe root damage from larval feeding. White-fringed beetle larvae decorticate the thin bark of slash and loblolly pine roots; the thicker bark of longleaf pine, especially at the root collar, may cause the larvae to bore to the phloem tissues. The adult beetles feed little to none on pine foliage. These insects are difficult to control and well protected by the soil; and methods for estimating pest population levels in the soil and the risk of economic damage to seedlings are not yet available.

20.6.1.2 Management strategies in the nursery

In a new nursery, proper site preparation should include thorough disking of any sod. For nursery compartments that were fallow, soil disturbance should be maximized to expose soil insects to adverse conditions (desiccation, heat, bird predation). On previously pine-forested sites, fresh stumps and other attractive slash should be removed or destroyed before pine seed are sown.

Rotating crops by alternating production of seedlings with that of cover crops — a common practice in many forest-tree nurseries — will reduce losses from insects, as well as other pests. The cover crops selected should provide the desired nutritional and organic amendments to the soil, but should not be attractive to pests. Leguminous cover crops in sandy soils are particularly susceptible to infestation by the lesser cornstalk borer [*Elasmopalpus lignosellus* (Zeller)]. Mole crickets and armyworms may spill over into pine seedling beds if allowed to build up in cover-crop fields.

Clean cultivation (minimal stubble or crop debris) in fall and winter lessens or eliminates populations of soil-inhabiting insects (lesser cornstalk borer, armyworms, white grubs). Disturbing the microhabitats established in crop residues, leaf litter, and other organic matter exposes pests to deleterious winter conditions.

Clear lanes between nursery beds and borders of natural grass and weeds should be maintained to lessen risk of pest damage. The greater the open area, the more likely pests will be exposed to adverse conditions — natural enemies, temperature extremes, desiccation, or starvation — when crossing from edge to bed. Borders of susceptible pine species should be removed if pests repeatedly infest the same or similar species of seedlings in the nursery. For example, removing a loblolly pine windbreak will lessen the risk of pine tip moths in loblolly pine nurseries. Likewise, nearby agricultural crops should be monitored for presence of potential pests because uncontrolled infestations may spill over into the pine crop.

The risk of pest problems can be minimized through scheduling time of sowing and harvesting or incorporating of a cover crop. Early sowing and harvesting of a millet or soybean cover crop can reduce the damage caused by the lesser cornstalk borer. After thorough disking of the soil, a second cover crop (e.g., rye grass) may be considered to prevent soil erosion and add organic amendments.

Insecticides have primary and secondary effects which must be considered in a forest nursery operation [1]. Primary effects — destruction of certain insects or insect groups by active ingredients — are well documented for registered insecticides. Secondary effects — seedling phytotoxicity, impact on nontarget organisms, and pest resistance — are less well understood and usually not on insecticide labels. All insecticides new to a nursery should be tested on a small area of pines and observed for phytotoxicity. Beneficial arthropods (insects and mites) are more susceptible to insecticides than are the target pests [107]. Insecticide applications should be based on actual need; "insurance" applications can suppress populations of beneficial arthropods such that they no longer control pests, thus causing pest populations to rapidly increase. Insecticides with narrow-spectrum toxicity (i.e., toxicity specific to a pest insect group or species) should be used whenever possible. **DIPEL®,** specific to lepidopterous larvae, and LECONTVIRUS®, specific to redheaded pine sawfly larvae, are good examples of narrow-spectrum toxicity insecticides. Routine, long-term use of an insecticide can promote pest resistance which may reduce the effectiveness not only **of** the applied insecticide, but perhaps of all insecticides within the same chemical group. Insecticides are useful tools in the management of a nursery; however, consideration must be given to the advantages and disadvantages of their use [47].

20.6.1.3 Management strategies in the field

The best recommendation for minimizing the risk or impact of a pest infestation is to plant the right species on the right site (see chapter 11, this volume). The net effect is a maximization of resistance (tolerance, nonpreference, or antibiosis) of the host plant to potential or ever-present pests. Tolerance is a resistance in which the plant shows an ability to grow and reproduce itself or to repair injury in spite of supporting a pest population about equal to that damaging a susceptible host. Nonpreference denotes a group of plant characters and insect responses that lead to or away from the use of a particular plant or variety for oviposition, food, or shelter. Antibiosis is expressed as adverse effects on the insect's life history, e.g., reduced fecundity, decreased size, abnormal life span, or increased mortality [113]. Beyond planting the right species on the right site to maximize resistance, site selection, proper spacing between trees, diversity of age classes within a broad management unit, sanitation-salvage cuttings, thinnings, and the like all enhance a tree's ability to cope with a pest should it invade a stand. In many cases, a young stand growing vigorously should achieve crown closure at an early age, a growth milestone that minimizes the risk of future infestation by insects such as pine sawflies and pine tip moths.

One of the best examples of an **IPM** approach for controlling insect pests is that developed for reproduction weevils (pitch-eating weevil, pales weevil) [111]:

- **Logging and planting date:** Generally, the risk of a weevil problem in a new stand is minimal if the area was clearcut and site prepared before July 1 of the year before outplanting. Weevils attracted to a stand cut before July generally leave by late summer or midfall of the same year; the brood (offspring of the parent adults) weevils will also emerge the same year. Therefore, seedlings planted in the upcoming year should experience no weevil problem. However, areas clearcut or site prepared (residual pines cut) during or after July will allow adult weevils to overwinter on site until late winter to midsummer of the next year. Brood weevils will emerge from early spring to late summer of the next year. Waiting 1 year will eliminate the risk of damage by feeding weevils.

- **Nonhazard sites:** Weevil problems do not develop on sites that were formerly old fields or in hardwoods or from direct pine seeding. Suitable food, habitat, and attractive stimuli are absent from fields and hardwood sites. Seedlings grown directly from seed are not large enough for weevil feeding and therefore escape when adult weevils emerge from stumps and roots.

- **Chemical control:** Three treatments are registered for reproduction weevils: (1) top dip of Imidan® before planting, (3) Furadan-clay slurry dip before planting, and (3) Dursban® foliage-stem spray after planting. The decision to use chemical control assumes that the present value of the timber gained through immediate regeneration is greater than the present value of control cost. Good control can be expected from any of these methods except when weevil populations are execessive.

Several types of weevil traps, baited with freshly cut pine stems or other attractive materials, have been developed in an effort to correlate numbers of attracted weevils before planting with subsequent seedling damage. Unfortunately, correlations have been poor. At best, trapping should be viewed as a mechanism that may provide some insight to aid decision making.

20.6.2 Diseases

Southern pine seedlings are susceptible to a variety of diseases (see Appendix A20.3, this chapter). The impact of nursery diseases is often substantial and may be assessed in terms of losses resulting from (1) nursery seedling mortality, (2) reduced seedling quality or the culling of unacceptable seedlings, (3) impaired seedling field performance (reduced growth and continuing mortality) due to latent disease development, (4) quarantine of seedling crops due to infection and concomitant response of government regulatory agencies, or (5) reduced forest productivity due to acreage not successfully regenerated. The impact of field diseases may be equally or more substantial, but is measured primarily in terms of (1) lost productivity, (2) reduced product quality, or (3) costs incurred during the regeneration of stands lost to disease.

20.6.2.1 Understanding nursery diseases

Sources of disease. — Effective management of nursery diseases is facilitated by knowing the source(s) of inoculum of the pathogen(s) involved. Bloomberg [22] identified five sources of forest nursery diseases: air, soil, water, organic residues and seed sources. The following discussion provides a framework for consideration.

Many disease-causing organisms enter the nursery by means of airborne spores. For example, fusiform rust is introduced into seedling crops through airborne sporidia (basidiospores) produced on the leaves of susceptible oaks on or near the nursery site. Brown spot needle blight enters the nursery through airborne spores and then spreads within susceptible seedlings through additional spores produced on infected needles throughout the growing season.

Some root diseases can be initiated by airborne spores, but most originate from soilborne propagules (e.g., spores, microsclerotia) that enter nursery seedbeds through contaminated soil amendments, water (e.g. from ponds), or mulches (e.g., pine straw) or through movement of contaminated soil particles by wind or water erosion. On the other hand, some root diseases are caused by endemic root pathogens which simply take advantage of the abundance of susceptible host-root tissue and the perfect ecological niche so frequently provided by the nursery soil environment. Complete eradication of soilborne pathogens from an infested soil is rarely, if ever, achieved. Once a nursery has sustained losses to certain soilborne pathogens, the potential for future losses is always present.

Lastly, infected or contaminated pine seed as a source of nursery disease should not be overlooked. For example, evidence strongly indicates that many seedling pitch canker infections are initiated via infected or contaminated seedlots (see Fig. 20.2).

Abiotic versus biotic factors. — Nursery seedlings are often vulnerable to injuries which may appear as diseases or may render seedlings vulnerable to pathogenic infections. Diseases resulting from mechanical injuries, stress, chemical toxicities, or extremes in environmental conditions are referred to as abiotic (i.e., caused by nonliving agents). Diseases caused by living organisms such as bacteria or fungi are called biotic. It is essential to determine whether a disease is abiotic or biotic, and key to sorting out the difference is the pattern of occurrence within seedbeds in both space and time. For example, an abnormality occurring simultaneously and uniformly across most or all of a nursery and within a few days of fertilizer or pesticide application suggests an application problem, thus an abiotic disease. Biotic infections rarely, if ever, occur simultaneously and uniformly across most of a nursery. Additionally, any disease found in a distinct mechanical pattern (e.g., straight lines, regular intervals, uniformly in a single seedbed) is unlikely to be biotic. Although biotic diseases may occasionally appear in regular patterns, such patterns usually reflect an abiotic condition that is injuring or stressing seedlings, or perhaps providing a regular distribution of inoculum within seedbeds. Bloomberg [22] provides a thorough treatise of nursery disease development within a spatial and temporal context.

Evaluation. — Nursery diseases must be evaluated to determine their identity or cause(s), magnitude, and anticipated progress (prognosis). With this information the nursery manager can then formulate appropriate responses which may vary from doing nothing, to immediately taking a suppressive or remedial action (e.g., roguing or destroying infected seedlings, applying a fungicidal spray), to implementing preventive strategies to minimize or eliminate similar problems in future crops.

Evaluating disease (and insect) problems can be compared to detective work. A keen sense of observation and an ability to ask pertinent questions are essential elements of the evaluation process. When did the problem first appear? Is the situation worsening or the damage spreading? What is the distribution of the disease: random occurrence or recognizable patterns (e.g., patches, straight lines, circles)? Do affected seedlings exhibit any definitive symptoms (e.g., tip blight, stem lesions, root necrosis, resinosis)? Is the problem related to irrigation riser lines, ends of seedbeds, windbreaks, soil drainage irregularities, seed source, or seedlot? Have affected seedlings received any unusual cultural treatment, or have they inadvertently been overlooked during a critical nursery operation? Unless the right question is asked, the problem may well remain undiagnosed.

Certain nursery diseases cannot be specifically identified without laboratory isolation and microscopic observation of the pathogen(s) involved. Where specific identification of causal agents is desirable or required for developing appropriate strategies, nursery managers are strongly advised to consult qualified specialists for assistance.

20.6.2.2 Management strategies in the nursery

Treatment versus prevention. — Unlike diseases which are initiated in the field, and which are typically controlled by prevention or avoidance, some nursery diseases can be effectively treated if diagnosed early. Treatment in nursery seedbeds is generally a matter of suppressing or retarding the spread of a disease (from seedling to seedling) after it is initially detected, although certain treatments may retard disease progress within or upon infected seedlings. Symptomatic and infected seedlings are rarely cured in the conventional sense of the word. Treatment may involve the application of specific fungicides or fertilizers, roguing of infected seedlings, or alteration of cultural practices (e.g., irrigation) or growing conditions (e.g., seedbed drainage). The fact that nursery diseases are often amenable to treatment and treatment is pursued is simply a matter of logistics and economics. Seedlings in nurseries are more accessible than seedlings in a plantation, and equipment and labor are on hand. In addition, a hectare of nursery seedlings (several million seedlings) is far more valuable than a hectare of pines in a plantation (several hundred seedlings).

Although many nursery diseases can be treated once detected and diagnosed, three important factors should always be kept in mind: (1) for some diseases, there are no legal or effective treatments (e.g., fungicides) (2) some nursery diseases are ephemeral (i.e., infections occur and symptoms appear and then disappear over a short time corresponding to passing environmental conditions or periods of host susceptibility) and are not sufficiently threatening to justify the expense of treatment, and (3) disease prevention in nurseries is far preferable to disease treatment, because prevention is generally more efficacious.

Prevention of many potentially serious nursery diseases is often best achieved indirectly through careful management. For example, certain root diseases can be prevented or suppressed by maintenance of adequate soil moisture and seedbed drainage, beneficial levels of soil organic matter, and appropriate soil pH. Seedbome diseases may be prevented as well through the production or acquisition of clean, disease-free seed and, where appropriate, treatment of contaminated seedlots with fungicides or disinfectants. It is important to note that in certain situations management strategies may, of necessity, shift from strict avoidance by preventing pathogen introduction into nursery seedbeds to tolerance by maintaining populations and activity at levels which induce only economically acceptable losses. For example, dangerous population buildups of certain soilborne pathogens (e.g., charcoal root rot fungus) may be prevented by using nonhost cover crops during fallow years. Populations or activity of other pathogens may be effectively suppressed by one or more management strategies including soil fumigation, use of selected fungicides, application of specific fertilizers, and use of certain organic soil amendments or mulches.

The judicious application of fertilizers, pesticides, herbicides, and even irrigation is important to avoid injuring or stressing seedlings, which may predispose them to infection by stress-related pathogens such as the charcoal root rot fungus. Detailed records of past occurrences of disease and related management practices may be useful to avoid repeating mistakes. Notwithstanding the above, disease prevention is sometimes best achieved directly through practices such as soil fumigation (appropriate in nurseries or seedbed soils with recent histories of harmful root diseases) or preventive fungicides (appropriate for fusiform rust and brown-spot needle blight in nurseries producing susceptible hosts).

Chemicals. — Nurseries, together with seed orchards, are undoubtedly the arena of the most intensive reliance upon applied chemicals (heavy and repeated applications of fertilizers, fungicides, insecticides, herbicides, and soil fumigants) in forestry. Carefully applied, nursery chemicals generally provide benefits which more than justify their costs and risks. However, in recent years scientists and nursery managers alike have become increasingly aware of potentially adverse impacts of nursery chemicals on personnel safety, the environment, and seedling quality.

Safety and environmental hazards associated with the use of pesticides are becoming increasing well documented and should always be a concern for nursery managers. Perhaps less well known, however, are some of the side effects of chemicals on disease development and seedling quality. For example, certain diseases are exacerbated by the application or abundance of certain inorganic fertilizers [80, 121]. Evidence is mounting that the pitch canker fungus is highly responsive to and more aggressive on seedlings supplied with excessive or luxuriant levels of certain nitrogenous fertilizers. Soil fumigation, a very useful tool for controlling various soilbome root pathogens as well as certain weeds, is nondiscriminatory and kills beneficial soil microorganisms (including mycorrhizal fungi, soil saprophytes, and organisms which may be antagonistic to soilbome pathogens) as well as harmful pests. Serious repercussions can result from soil fumigation applied improperly. Specifically, if a soil fumigant is applied in the wrong formulation, at less than optimal rates, or under less than favorable environmental conditions (e.g., soil temperature and moisture), certain root diseases may worsen following fumigation [87, 132]. More recently, the widespread use of Bayleton®-based sprays for controlling fusiform rust in nurseries has heightened awareness of the potential for unwanted biological impacts from certain nursery chemicals. Although extremely effective against fusiform rust, Bayleton can suppress the normal development of ectomycorrhizae [94].

20.6.4. Management Strategies in the Field

Basic and applied research in forestry over the past 3 decades has resulted in methods for producing high-quality, genetically improved, southern pine seed and for growing sufficient quantities of healthy seedlings for regeneration.

These accomplishments are meaningless, however, if pests in the field significantly reduce seedling survival and growth or the volume and quality of the desired products at rotation.

A number of forest-tree diseases can cause significant losses during southern pine stand establishment. Some, such as fusiform rust, occur across broad geographic areas of the southern United States. Others, such as brown-spot needle blight of longleaf pine and white pine blister rust, caused by *Cronartium ribicola* J.C. Fischer ex Rabenh., are restricted by distribution of the hosts or environmental conditions.

Diseases such as eastern gall rust *[Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *virginiana* and *C. quercuum* f. sp. *echinata],* needle casts *(Lophodermella* spp., *Ploioderma* spp., and other species), and needle rusts *(Coleosporium* spp.) are widely distributed throughout the South, but rarely cause significant economic concern except in high-value crops such as Christmas trees.

Fusiform rust or brown-spot needle blight generally causes the greatest damage during the first 5 years of stand development. Conversely, diseases such as annosus root rot or littleleaf disease, caused by *Phytophthora cinnamomi* Rands, may only become serious problems later on, both directly and by predisposing affected stands to attack by the southern pine beetle, *Dendroctonus frontalis* Zimm., as has been shown for annosus root rot [3] and littleleaf disease [16].

Fusiform rust, which is currently the most serious disease of the commercially important southern pines, provides an excellent example of how pest management decisions made at the time of regeneration may be important to the subsequent survival, growth, and productivity of a stand of slash or loblolly pine. Pine species, relative resistance of families or seed sources planted, intensity of site preparation (mechanical, chemical, or both), presence and abundance of the oak alternate host in adjacent areas, soil drainage, fertilization, and other factors may profoundly affect the subsequent incidence of rust on a given site (see Appendix A20.3, this chapter). Decisions on the management of young, fusiform rust-infected slash pine stands can be guided by the use of systems that estimate future rust-associated mortality based on the incidence of stem galls at ages 3 or 5 years [40, 105, 142]. Similar predictive equations have also been developed for loblolly pine [142].

In addition to the diseases that affect southern pines directly, certain disease-insect interactions are known or are strongly suspected. As mentioned earlier, annosus root rot and littleleaf disease are known to predisopose southern pines to attacks by the southern pine beetle. The eastern pine weevil is known to be a vector of the pitch canker fungus [21]. Pine tip moths are suspected to be involved in the pitch canker disease complex and with fusiform rust. Fusiform rust galls are frequently attacked by a variety of insects, creating wounds that are often then infected by the pitch canker fungus or by decay-causing pathogens such as *'notion's circinatus* (Fr.) Gilbertson [53, 77].

Once a stand of southern pines is established, it is rarely either economically or practically feasible to apply pesticides. Therefore, pest management must strongly depend on the recognition of the potential for damage, planned prevention, and good silviculture. Reacting to a disease or insect outbreak after the fact is sometimes the only option available to a forest manager, but such responses are rarely as effective as prevention.

The major, economically important diseases of southern pines, such as fusiform rust and pitch canker, and insects, such as the southern pine beetle, have reached their present destructive status concurrent with our efforts to produce more fiber faster in large, pure stands of a few commercially important species. These pests frequently negate the potential gains made from genetic tree improvement and intensive management techniques. Therefore, planned disease and insect prevention must become an integral component of good forest management in the South.

Appendix A20.1: Identification and management of insects affecting cone and seed production in southern pine seed orchards. Identifying characteristics in table include only those stages of insect development likely to be found on trees.

Order and species	Host[1]	Recognition/life histories	Management	References
Coleoptera				
White pine cone beetle *Conopthorus conipera* (Schwarz)	6	Adults black, covered with moderately long hairs, head directed downward; ca. 4 cm long. Larvae cream-colored, legless, C-shaped. One generation/year. Adults overwinter in cones and emerge in late spring. Females attack and kill second-year cones. Entrance holes in the base or stalk of cones marked by pitch tubes. Eggs are deposited in cone axis. Larvae feed on seed and cone tissues for a month, completely destroying the cone interior.	Removal of mature cones containing overwintering adults from orchards and surrounding areas may reduce orchard populations. Carbofuran (Furadan®) reduced beetle populations; however, its use has been cancelled.	[26, 57]
May or June beetles *Phyllophaga luctuosa* (Horn) *Phyllophaga prununculina* (Burmeister) *Phyllophaga micans* (Knoch) *Polyphylla occidentalis* (L.) *Phyllophaga* spp. *Polyphylla* spp. Green June beetle *Cotinis nitida* L.	1, 2	Adults brown to black, ca. 2 cm long. Most species have 3-year life cycle, but they are not synchronized. Pupation occurs in the soil; some adults emerge each year in early spring and feed nocturnally on foliage of pines and hardwoods. Adult *P. micans* feed on female flowers of loblolly pine for a month between stages 3 and 5 of strobilus development (Fig. 20.1). Feeding begins at the flower tip, and the entire flower may be consumed. Eggs are deposited in soil and hatch in 3–4 weeks. Larvae feed on decaying vegetation and tender plant roots.	Insecticidal control with isophenfos (Oftanol®) or bendiocarb (Turcam®). Bio-insecticidal control with *Bacillus popillae* or *B. lenomorbus* (Doom®) for Japanese beetle, *Popillia japonica* Newman. One or more soil applications may be necessary to adequately control the larve (white grubs). The advantage of the bacterium: it causes a milky disease specific to the beetle larvae and thus has a very limited risk to the environment.	[57, [65, 76, 97]
Pine sawyer beetles Southern pine sawyer *Monochamus titillator* (F.) Carolina sawyer *Monochamus carolinensis* (Oliver)	1, 2	Adults dark brown with irregular patches of brown and gray and two large patches of brown on each elytron; body slender and elongate with antennae as long as or longer than body. One or more generations/year. Adults emerge in spring and and summer and feed on tender bark of shoots and young female strobili. Females excavate elliptical pits in bark through which they oviposit into phloem. Larvae bore for 1–2 months in inner bark, then enter xylem. Pupation occurs the following spring or summer.	Sanitation-cut severely stressed or damaged trees from the seed orchard. Parent and brood adults will feed on bark of nearby healthy trees. Wounds may serve as infection courts for pitch canker (see Appendix 20.3, this chapter) or pine wood nematode [*Bursaphelenchus xylophilus*]	[4, 28, 52, 86]
Diptera				
Cone resin midge *Asynapta hopkinsi* Felt Southern cone gall midge *Cecidomyia bisetosa* Gagne *Resseliella silvana* (Felt)	1–4	Larvae with small head capsule and flattened, tapered body. Larvae and pupae yellowish-white to pale reddish-orange; 2–3 mm long. Posterior body segments of cone resin midge are smooth without spines; terminal body segments of its larvae are forked. Larvae feed gregariously on scale and seed surfaces, causing resinosis and death of attacked scales. Entire cones may be killed.	Although entire scales or cones may be killed, the percentage infested is usually low and no control is warranted.	[76]

Hemiptera				
Southern pine seed bug *Leptoglossus corculus* (Say) Shieldbacked pine seed bug *Tetyra bipunctata* (Herrich-Schaffer)	1–6	*Southern pine seed bug:* Adults reddish-brown with black and white markings, wings brown with a white zigzag stripe; ca. 2 mm long with leaflike expansion on hind legs; head is elongated. Nymphs resemble adults but lack wings; stages 1–4 mottled reddish-brown, last instar shaded gray. Several generations/year with all stages present during spring, summer, and fall. Young nymphs feed on needles and conelets; older nymphs and adults feed on seed within cones. *Shieldbacked pine seed bug:* Adults yellowish to dark reddish-brown with black mottling; shield-shaped body; ca. 1.5 cm long. Nymphs gray to reddish-brown and resemble adults, but lack wings. One generation/year. Adults overwinter in soil, remain inactive until summer, then deposit eggs on pine foliage. Late-stage nymphs and adults feed on seeds within cones.	Insecticidal control with fenvalerate (Asana XL®) or permethrin (Ambush®). Make first application of fenvalerate or permethrin within 30 days of female flower closure; repeat applications at intervals of 4 weeks, but do not exceed 6.3 lb ai/ac/yr of fenvalerate or six applications of permethrin.	[31, 57, 76]
Lepidoptera				
Pine conelet looper *Nepytia semiclusaria* (Walker)	1, 2, 4	Forewings grayish tan with pair of brown scalloped lines, hind wings with single scalloped line; wingspan 2.5–3.0 cm. Pupa tan with white markings. Larvae with brick red dorsal stripe and paired yellow lateral stripes separated by black and white lines; head orange with black spots; ca. 2.5–3.0 cm long. One generation/year. Overwinters as egg. Larvae hatch during spring and damage female flowers; then, depending on pine species, complete development on flowers, conelets, or new needles. Pupation occurs in a web-like shelter among the needles from late spring to early summer.	Insecticidal control with malathion (Cythion®). Year-to-year damage of consequence appears to be sporadic.	[55, 56, 76]
Shortleaf pine cone borer *Eucosma cocana* Kearfott	1, 4	Forewings mottled rust-red and silver, hind wings dark gray; wingspan 1.7–2.8 cm long. Larvae light pinkish-purple with a dark patch on top of the last abdominal segment (anal shield) and brown head; 1.0–1.5 cm long. One generation/year. Overwinters as pupa; moths emerge in spring. Eggs deposited in groups under scales of cone stalks. Young larvae feed gregariously in conelets and later feed individually, destroying cones on the same branch resulting in a grouping of newly attacked cones. Cones are packed with frass and often covered with exit holes and frass. Larvae mature during summer and pupate in soil.	Insecticide carbofuran (Furadan®) reduced cone borer damage; however, its use has been cancelled.	[57, 58, 76]
White pine cone borer *Eucosma tocullionana* Heinrich	5	Forewings marked with bands of dark brown and tan scales, hind wings dark brown with gray fringe; wingspan 1.2–1.9 cm. Larvae similar in size to shortleaf pine cone borer, pale greenish brown without a dark anal shield. Life history incompletely known. One generation/year. Pupation probably occurs within cones; adults emerge during late summer. Damage to conelets begins in late spring. Attack patterns are similar to those of the shortleaf pine cone borer.	See above	[57, 76]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.1 (continued)

Order and species	Host[1]	Recognition/life histories	Management	References
Slash pine seedworm *Cydia anaranjada* Miller Longleaf pine seedworm *Cydia ingens* Heinrich Eastern pine seedworm *Cydia toreuta* (Grote)	1–3	Slash pine seedworm has orange forewings; others have metallic gray forewings with silver bands; wingspans 1.0–2.0 cm. Pupae 5–10 cm long. Larvae 1.0–1.5 cm long; cream-colored with light brown heads. Life histories similar. One generation/year. Adults emerge in spring; eggs deposited on stalks or surfaces of second-year cones. Young larvae enter cones between scales (no visible signs), then enter individual seeds; completely consume endosperm, seed packed with frass. Silk-lined tunnel made between seeds. Larvae complete development in fall; overwinter in cone axis; pupate in spring in axes.	Insecticidal control with azinphos-methyl (Guthion®). Apply once between May 1–15. Remove mature cones with overwintering larvae from orchard and surrounding area to reduce local seedworm populations and damage levels.	[55, 57, 76, 98, 99]
Coneworms	1–6	Forewings usually marked with tufts of scales and colored bands; wingspans 2.0–3.0 cm. Eggs oval-shaped, 0.4–0.6 mm wide, 0.6–1.0 mm long; usually cream-colored at first, turning reddish-orange at eclosion. Mature larvae 1.5–2.5 cm long. Last instar descriptions follow below. Coneworms have 1–6 generations/year, depending on species and geographical locations.	Insecticidal control with azinphos-methyl (Guthion®), fenvalerate (Asana XL ®), or or permethrin (Ambush®). Apply azinphos-methyl within 30 days of conelet closure; apply no more than 6 times/year. Time applications to coincide with moth flight (blacklight traps, pheromone traps). Make first application of fenvalerate or permethrin within 30 days of female flower closure. For webbing coneworm first apply within 1 week of female flower closure or peak pollen flight. Repeat applications at 4-week intervals. Do not exceed 6.3 lb ai/ac/yr of fenvalerate or six applications/year of permethrin.	[27, 36, 55, 57 58, 76, 104, 106]
Southern pine coneworm *Dioryctria amatella* (Hulst)	1–4, 6	Forewings dark grayish-brown to black with white markings and zigzag stripes, hind wings tan. Larvae dark purplish-brown dorsally, greenish white ventrally, and small dark spots on abdomen. Several overlapping generations/year. Usually overwinters as young larvae which feed on strobili during early spring, then migrate to developing shoots. Some larvae mature in shoots, others migrate to cones. Larvae also associated with fusiform rust galls and strobili infected with southern pine cone rust. Second-year cones attacked throughout summer and fall. Pupates in infested host materials.	See above	See above
Blister coneworm *Dioryctria clarioralis* (Walker)	1–3	Forewings rusty-brown with grayish-white cross-lines and wide dark band near base; hind wings rusty-tan. Larvae brownish-orange, tinged gray dorsally but paler ventrally. Three generations/year. Young larvae overwinter in infested materials and feed, externally, internally on flowers, buds, shoots, conelets, and young cones. Larvae attack base of strobili, and entrance hole is covered with shield (blister) of silk and resin filled with frass. Pupates in twig in cocoon covered with bark scales.	See above	See above

Webbing coneworm *Dioryctria disclusa* Heinrich	1, 4	Forewings yellowish-orange to reddish-brown with white stripes and markings, hind wings smokey-tan. Raised tufts of scales absent from wings. Larvae grayish-buff to olive-green dorsally and paler ventrally. One generation/year. Moths emerge late spring to midsummer depending on geographical location. Young larvae diapause until the following spring and then infest young second-year cones during spring and early summer. Larvae bore entrance hole in cone base and cover it with mass of tightly webbed frass; cones are hollowed out and often contain silken material. Pupates in infested cones.	See above	See above
South coastal coneworm *Dioryctria ebeli* Mutuura and Munroe	1–3	Forewings dark gray with light gray markings and cross stripes; pair of greenish-yellow spots near wing bases. Raised tufts of scales absent on forewings, hind wings are light grayish-tan. Larvae dark purple to brown dorsally and paler ventrally. Up to six generations/year. Larvae overwinter in shoots and fusiform rust galls; attack cones throughout summer and fall, often secondary invaders of damaged cones. Conelets infected with southern pine cone rust are frequently attacked during spring. Pupates in thin cocoons apparently in soil.		
Loblolly pine coneworm *Dioryctria merkeli* Mutuura and Munroe	1–4	Forewings brown with patches of rust, darker shading, and gray stripes; hind wings pale grayish-tan. Larvae dark blue-black dorsally and blue-green ventrally. One generation/year. Young larvae overwinter beneath bark scales and infest male, female flowers in spring. Entrance holes usually marked with mass of resin and frass. Larvae migrate from flowers and complete development in shoots (slash and longleaf pines) or in second-year cones. Mature larvae are inactive throughout summer, then pupate and emerge as adults from late summer to early fall.	See above	See above
Thysanoptera				
Slash pine flower thrips *Gnophothrips fuscus* (Morgan)	2	Adult dark brown to black, slender with tapered abdominal tip; ca. 2.0 mm long; wings yellowish-orange when present. Larvae similar to adult in size and shape; pale yellow to dark yellow. Possibly three generations/year. Adults may overwinter in crowns of mature trees, then migrate to understory pines to reproduce. Eggs, larvae, pupae, and adults have been found on understory slash pines from early spring to fall. On mature trees the adults feed externally on scales and bracts of flowers for ca. 1 month (stages 1–4 of flower development or twig-bud stage through pollination). Feeding results in small punctures and abrasions marked by exuded beads of resin and can kill flowers or distort cone growth while decreasing seed yields.	Insecticidal control with malathion (Cythion®) or acephate (Orthene®). Make first application when female flowers are in twig-bud stage (between stages 1 and 2 of flower development) and second on application 1 week prior to maximum flower receptivity to pollen (during stage 4 of flower developent). Removal of young understory pines from orchards and adjacent areas may reduce local population levels of the thrips.	[32, 39, 54, 119]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.2: Identification and management of insects affecting pine seedlings and young trees in nurseries and field (0 to 5 years). Identifying characteristics in table include only those stages of insect development likely to be found on trees.

Feeding group	Host[1]	Recognition/life histories	Management	References
Sucking insects and mites				
Spider mites Spruce mite *Oligonychus ununguis* (Jacobi) Southern red mite *Oligonychus milleri* (McGregor) Twospotted spider mite *Tetranychus urticae* Koch	1–6	Adults and immatures vary in color from pale yellow to brown, red, and green and may be spotted. Eight-legged, <0.5 mm long, and oval. Multiple generations/year. Significant population increases can occur in late summer and early winter, especially during droughty weather. Mite feeding results in curling, mottling, yellowing, or bronzing of needles. Silk webbing or matting may occur between needles. Severely damaged nursery seedlings may exhibit poor field survival.	Minimize moisture stress in nurseries. Miticidal control with malathion (Cythion®), dicofol (Kelthane®), propargite (Omite®), dienchlor (Pentac®), tetradion (Tedion®), and ethion (Nialate®). Make first application at first sign of spider mites, second application 7–10 days later. Subsequent applications may be needed.	[47]
Scale insects Pine scale *Chionaspis heterophyllae* (Cooley) Pine needle scale	1–6	*Pine scale and pine needle scale (adult females)*: Oyster-shaped, white, waxy body; one yellowish tip, and 3–4 mm long. Nymphs yellowish-orange to red, mobile, and < 1 mm long. One to two generations/year.	Insecticidal control with dimethoate (Cygon®, De-Fend®), malathion (Cythion®), or ethion (Nialate®). Control may be enhanced by suppressing ants that are tending scales.	[13, 47, 51]
Chionaspis pinifoliae (Fitch) Pine tortoise scale *Toumeyella parvicornis* (Cockerell) Striped pine scale *Toumeyella pini* (King) Virginia pine scale *Toumeyella virginiana* (Williams & Kosztarab)		*Tortoise scales (adult females)*: Round, raised, light to dark brown body with white streaks or patches, and ca. 6 mm long. Nymphs pinkish-orange to red body, mobile, and 1–2 mm. One or two generations/year. *All scales*: High population level may kill foliage, branches, or seedlings. Black sooty mold may become dense. Stunting, curling, yellowing, or distortion of needles (pine scales only) or grayish appearance of lower branches of seedling. More common in field than nursery.	Natural enemies generally keep scale insects under control. If scales exhibit small holes on top side, minimize insecticide use – natural enemies may gain control of scales.	
Tarnished plant bug *Lygus lineolaris* (Palisot de Beauvois)	1, 2, 6	Adult head yellowish-brown, body yellowish with few black markings to reddish-brown, or almost completely black with few yellow markings; ca. 4.9–6.0 mm long. Nymphs yellowish-green, 4 black dots on thorax and 1 dot on base of abdomen; ca. 2–4 mm long. Two or three generations/year. Adults overwinter in leaf litter, dead weeds; in early spring, feed on newly developing buds and shoots. Pines in nurseries damaged from time of germination to August: multiple meristems, curling needles, and stunted growth. Bugs not usually directly observed – sticky traps can can be used to monitor bug population activity and levels.	Remove preferred host plants from edges of nurseries and destroy favorable overwintering sites to reduce bug populations. Insecticide control with fenvalerate (Asana XL®), spraying nursery edges 2 weeks prior to pine seed germination, pine seed at germination, and several weekly applications of seedlings.	[46]
White pine aphid *Cinara strobi* (Fitch) Carolina conifer aphid *C. atlantica* (Wilson)	1–6	Adults and immatures soft-bodied, pear-shaped; white, green, yellow, gray, brown, black: wings may be present, and 1–6 mm long. Multiple generations/year. Resinosis and/or stunting, curling, yellowing, or distortion of	Same as for scale insects.	[13, 51]

C. pinea (Mord wilko) *C. taeda* Tissot *C. watsoni* Tissot *C. invora* (Wilson) *C. pergandei* (Wilson)		needles. Terminal bud damage may result in multiple meristems. Black sooty mold may become dense.		
Defoliating insects				
Pine webworm *Tetralopha robustell* Zeller	1–6	Larva light brown with four dorso-lateral stripes, head with dark stripes. Mature length ca. 2.0 cm. Three to four generations/year depending on geographical location. Pupae overwinter in soil; adults emerge in spring and deposit eggs on pine needles. Young larvae mine needles, then construct silken webs covered with frass. Older larvae clip needles and feed on them within nests.	Generally, no direct control measures are necessary. At low population levels, nests can be destroyed by hand. Insecticides dimethoate (Cygon®) and carbaryl (Sevin®) can be used to reduce high population levels.	[13, 51]
Pine sawflies		Adults thick-waisted wasps; light to dark brown background color, red-yellow-shite markings common; wings clear to light brown, veins prominent; ca. 5–7 mm long. Larvae usually whitish, yellowish, or greenish body with two or more darker stripes and/or row of dark spots; head red, brownish, or black; mature length ca. 1.8–2.5 cm. Cocoon light brown to dark reddish-brown, papery; ca. 7.1–10.0 cm long. One to four generations/year depending on species and climate. Pupate in duff or pine litter, in mineral soil, or under bark scales. Adult females lay eggs in slits sawed in pine needles. Small larvae feed on outer needle tissues; larger larvae consume entire needles. Larval colonies may migrate from one tree to another. Branches of heavily defoliated trees have a bottle-brush appearance.	Trees 5–10 years old most susceptible. Redheaded pine sawfly infrequently feeds on longleaf pine in nurseries. Conserve and promote diversity of host plants around plantations to enhance natural enemy species and numbers (small mammals, birds, insects). Frequently, natural epizootics (nucleopolyhedrosis viruses) decimate sawfly populations. Maximize stand diversity and promote early crown closure. Insecticidal control with malathion (Cythion®) and carbaryl (Sevin®) can be used to reduce high sawfly populations.	[25, 44, 51]
Redheaded pine sawfly *Neodiprion lecontei*	3, 1, 2, 4			
Virginia pine sawfly *Neodiprion pratti pratti* (Dyar)	6			
Slash pine sawfly *Neodiprion merkeli* Ross	2			
Blackheaded pine pine sawfly *Neodiprion excitans* Rohwer	1, 4, 3			
Abbot's sawfly *Neodiprion abbotii* (Leach)	1, 3, 4, 2			
Loblolly pine sawfly *Neodiprion taedae linearis* Ross	1, 4			
Sand pine sawfly *Neodiprion pratti* (Dyar) subsp.	6			
Spotted pine sawfly *Neodiprion taedae taedae* Ross	1, 4			
Pine sawfly *Neodiprion virginianus*	6			
White pine sawfly *Neodiprion pinetum* Norton	5, 4			
Introduced pine sawfly *Diprion similis* (Hartig)	5, 4			
Introduced pine sawfly *Diprion similis*	5, 4			

Appendix A20.2 (continued)

Feeding group	Host[1]	Recognition/life histories	Management	References
Pine chafer *Anomala oblivia* Horn	1–6	Adult male beetle head and pronotum greenish-bronze, elytra dark tan, ca. 6.5 mm long; female light tan, ca. 9.0 mm long. Larva grublike. One generation/ year. Adults emerge from soil from late spring to early summer and feed on new needles, notching just above sheath, giving a brownish appearance to branch. Larvae feed on roots of various plants, including trees. Overwinter as larvae in soil; pupate in spring. More common in open pine stands and plantations. Typically, damage is not seen until the end of adult feeding period. Damaged needles may continue to grow.	Control is usually not warranted; where necessary, the insecticide carbaryl (Sevin®) is effective.	[51]
Pine colaspis *Colaspis pini* Barberca.	1–6	Adult rusty-yellow or brown with greenish reflections; 4.5 mm long. Larva subcylindrical, white; ca. 7 mm long. One generation/year. Adults emerge from soil late spring to early summer and feed on edges of needles, chewing towards the midrib, giving a bright reddish-brown appearance to crown (scorching effect). Larvae feed on roots of grasses and herbaceous vegetation. Overwinter as larvae in the soil; pupate in spring. More common in pines growing along grassland or isolated groups of pines in fields or yards.	See pine chafer above.	[51]
Cutworms Variegated cutworm *Peridroma saucia* (Hubner) Southern armyworm *Spodoptera eridania* (Cramer) Tufted white pine caterpillar *Panthea furcilla* (Packard) Armyworm *Pseudaletia unipuncta* (Haworth) and other spp.	1–6	Larvae vary in color; generally dull gray or brown background with faint to strong banding or stripes; stout, naked body; ca. 2.5 cm long. Several generations/ year depending on geographical location and climate. Feed on roots, stems, or foliage of seedlings in nurseries and first-year outplantings. Most damage occurs when seedlings are succulent. Feeding occurs at night; larvae in soil during daylight. Damage can be confused with damping-off.	Weeds and grasses along nursery borders plus cover crops may induce buildup of cutworm populations. Clean cultivation is strongly recommended in the nursery. Control in plantations is usually unwarranted. In nurseries, use insecticides diazinon (Diazinon®), carbaryl (Sevin®), or dimethoate (Cygon®).	[47, 51]
Bark and stem feeders				
Pine tip moths Nantucket pine tip mothor Rhyacionia *frustrana* (Comstock) Pitch pine tip moth *Rhyacionia rigidana* (Fernald) Subtropical pine tip	1, 4, 2 1, 2 2, 3, 1	Adults vary in color; head grey, whitish, or reddish with body rusty brown or grayish, wings rusty brown, silvery, patches of brick red and coffee brown; wingspan ca. 1.2–2.0 cm. Adults lay eggs on foliage and buds in early spring. Larva body pale yellow to orangish, head dark brown to black; ca. 8.0–12.5 mm long. Several generations/year depending on geographical location and climate. Larvae feed within needle sheaths, buds, and shoots. Pupate within damaged host material. Severe	Commercial pheromone traps are available to survey for pine tip moth populations and for timing of insecticide applications. Insecticidal control can be used to suppress tip moth populations: diflubenzuron (Dimilin®) and dimethoate (Cygon®).	[13, 47, 51, 145]

moth *Rhyacionia subtropica* Miller		damage can occur in young natural and planted stands, especially those growing off site. Growth loss and stem deformity can be considerable; however, infestation rates usually decline as trees reach 3 m tall or crowns grow together. Nursery beds of loblolly pine may experience notable damage in areas of dense pine tip moth populations. Longleaf pine and slash pine are at less risk of infestation.		
European pine shoot moth *Rhyacionia bouliana* (Schiffermuller)	3, 5			
Reproduction weevils Pales weevil *Hylobius pales* (Herbst) Pitch-eating weevil *Pachylobius picivorus* Germar	1–6	Adult reddish-brown to black; long snout on small head, light-colored patches of hairs on elytra; ca. 7–12 mm long. Larva cream-colored body, amber-colored head, legless; ca. 1.2 cm long. One or two generations/year depending on geographic location. Adults, attracted to logging areas or stands of damaged trees, feed on inner bark of fresh tops, stumps, twigs of residual trees, and stems of seedlings. Females lay eggs in bark of under ground parts of stumps and in roots. Larvae tunnel in phloem along length of roots. Pupate in host material. Adults emerge and feed on nearby trees with green bark; small to large patches of bark removed by feeding, may be applied as a preventive or resinosis may or may not be present. Adult weevils may feed year-round when winter temperatures are not near freezing.	Avoid placing fresh windrows near pine nurseries or young plantations; do not grow pines near pine lumber mills. For pine-to-pine sites, control can be effected by delaying planting of newly harvested pine sites for 9–12 mos. to allow time for parent and brood adult weevils to develop and leave the site. Insecticidal control may be necessary if a planting cannot be delayed. Insecticides chlorpyrifos (Dursban®) and carbofuran (Furadan®) for remedial action.	[51, 111, 112]
White pine weevil *Pissodes strobi* (Peck)	6	Adult brown, long snout on small head, irregularly shaped patches of brown and white scales on elytra and and body, especially near apex of each elytron; ca. 4–6 mm long. Larva cream-colored body, amber-colored head, legless; ca. 6 mm long. One generation/year. Adults feed on shoots of leader and upper branches of young white pines in spring. Females oviposit eggs under bark of terminal leader. Larvae tunnel downward in cambium under bark; pupate in host material by late summer. Adults emerge and feed on shoots of upper branches in early fall; hibernate in litter through winter.	Plant white pine with hardwood or under hardwood cover; on medium soils only, where soil matting or hardpan does not occur within 1 m of surface. Select and prune the least injured pines for improved final crop in heavily infested stands. Remove less desirable trees from white pine stands. Insecticides lindane (Lindane®) and oxydemton-methyl (Metasystox-R®) may be applied as a preventive action.	[48, 49, 50, 51]
Root feeders White grubs *Polyphylla* spp. *Phyllophaga* spp.	1–6	Adult beetles (May or June beetles) robust, oval, light yellow to dark brown; ca. 1.2–2.5 cm long. Larva C-shaped and creamy white, head amber-orange; well-developed legs and jaws; hind end bluish-black; ca. 2.5 cm long. One or more years required for development of a generation. Adults emerge from soil in spring, lay eggs in soil. Larvae usually feed on roots of weeds, grasses, and herbaceous plants. Damaged seedlings have discolored foliage, often severed at or 5–7 cm below groundline, and roots missing.	Avoid planting pine seedlings in freshly turned sod which often has dense grub populations. Insecticidal control of grubs in sod or at edges of nurseries can be achieved with isophenphos (Oftanol®) or bendiocarb (Turcam®).	[47, 51]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.2 (continued)

Feeding group	Host[1]	Recognition/life histories	Management	References
Mole crickets Northern mole cricket *Neocurtilla hexadactyla* Short-winged mole cricket *Scapteriscus abbreviatus* Scudder Southern mole cricket *Scapteriscus acletus* Rehn and Hebard Tawny mole cricket *Scapteriscus vicinus* Scudder European mole cricket *Gryllotalpa gryllotalpa* (L.)	1–6	Adult and immature (nymph) light to dark brown body; front legs strongly scooped for digging; ca. 3.0–4.0 cm long. One generation/year. Damaged seedlings exhibit loss of roots, pits in belowground parts of stems, and toppling. Slightly raised tunnels may be observed on the surface of exposed soil.	Often spill into a nursery from on-site vegetable gardens, preferred cover crops, or edges of nursery growing herbaceous plants. Insecticidal control with baits [propoxur (Baygon®), malathion (Cythion®)], or soil drenches [carbaryl (Sevin®), diazinon (Sprectracide®)]. Optimize control by applying insecticides when immatures are most prevalent, generally early summer; adults are very difficult to suppress.	[47, 51, 130]
Lesser cornstalk borer *Elasmopalpus lignosellus* (Zeller)	1–4, 6	Larva bright green to turquoise with brown longitudinal stripes; head dark brown to black. Mature length ca. 2.0 cm. Adult light to dark brown; wingspan of 1.6–2.4 cm. Female forewings uniformly dark brown to black; male forewings lighter colored and gray to black margins. Two to four generations/year. Females lay eggs in at base of host plants or on stems and lower leaves or in late spring. Larvae mine lowermost branches or begin subterranean feeding of stems and roots. Silk tunnels radiate from feeding sites, protect larvae from insecticide and other disturbances. Pupate in tunnels or soil litter. Damaged seedlings die and remain upright or fall over. Below ground, stem girdling, gall-like formations, or callous tissue around a feeding wound may be present.	Infestation is favored by susceptible host plants, sandy soils, and droughty weather. Cover crops such as soybeans, pearl millet, peanuts, sorghum, peas, and grasses can build up extremely high population levels of the lesser cornstalk borer. Fall or winter cleanup of plant residue and rotations with nonsusceptible cover crops can reduce borer problem. Early disking of cover crop may reduce borer population levels. Preventive insecticides include chlorpyrifos (Lorsban®) and diazinon (D.z.n.®). Chemical control is difficult because of protective silk tunnels constructed by larvae.	[42]
White fringed beetles White fringed beetle *Graphognathus leucoloma leucoloma* (Boheman) *Graphognathus minor* (Buchanan) *Graphognathus peregrinus* (Buchanan) *Graphognathus fecundus* Buchanan	1, 2	Larva creamy yellowish-white; C-shaped with a strong thoracic swelling. Mature larva ca. 1.2 cm long. Adult female (male unknown) light to dark gray or brown, with a lighter band along the outer margins of wing covers, and two paler longitudinal lines on each side of thorax and head; ca. 1.2 cm long. One generation/year. Eggs laid on plant stems, roots, soil. Larvae feed on roots, tubers, and underground stems. Overwinter as larvae; pupate in soil. Adults emerge from May to October. Over 380 host plant species; most common are peanuts, cotton, okra, velvetbeans, soybeans, cowpeas, sweet potatoes, beans, and peas. Larvae are pests of young pine planted on converted croplands in the South. Decortication or partial to complete removal of taproots, belowground portions of stems, and some lateral roots.	Oats and other small-grain cover crops are less preferred host plants because of fibrous versus taproot systems. Rotating cover crops (from preferred to less attractive hosts) minimizes buildup of beetle. Scalping (creating a furrow by pushing aside vegetative material and exposing mineral soil prior to planting pines) can reduce beetle damage. Herbicide applications for weed control may exacerbate level of beetle damage because grubs have only tree roots to consume after weeds die off. Chemical control is extremely difficult. Soil habitat and flightless nature of beetles combine to make a persistent pest once on site.	[45, 146]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.3: Identification and management of important diseases affecting the regeneration of southern pines in seed orchards, nurseries and the field (0 to 5 years). Identifying characteristics in table include only those most readily observed and key to diagnosis. (Note: Specific diagnosis in many cases cannot be determined without the aid of highly trained specialists and laboratory analysis.)

Disease/pathogen	Host[1]	Recognition	Management	References
Phytophthora root rot *Phytophthora cinnamomi* Rands *P. parasitica* Dastur	1–6 (esp. 6)	*Seed orchards, nurseries, and field*: Discoloration, wilting, poor growth, and mortality of seedlings and young trees. Slow to rapid mortality. Fine roots necrotic, black with cortex sloughing easily when roots pulled between fingertips. Larger roots, taproot/root collar resin-soaked and often supporting clods of resin-impregnated soil, especially with *P. cinnamomi* on sand pine. Often associated with impeded seedbed drainage, flooding, or fine-textured poorly drained soils. *P. cinnamomi* on sand pine known only in nurseries and planted stands (including seed orchards)- a definite threat to outplantings. *P.parasitica* occurs on sand pine in nurseries, typically in hot, wet summer periods; ephemeral and not a threat to outplantings.	Maintain good seedbed soil drainage. Fumigate nursery soils with methyl bromide and use appropriately labeled fungicides to minimize spread within infested seedbeds. Do not produce sand pine in nursery soils with a history of *P. cinnamomi* or ship seedlings infected/contaminated with *P. cinnamomi*. Avoid poorly drained areas and shallow, fine-textured soils when planting highly susceptible species such as sand pine. Also avoid soils where *P. cinnamomi* is known to occur. Be sure planting stock is free of *P. cinnamomi*. Fungus can be introduced into plantations from nurseries via infected/contaminated nursery stock.	[10, 15, 89, 120]
Charcoal root rot *Macrophomina phaseolina* (Tassi) Goid.	1–4, 6	*Seed orchards, nurseries, and field*: Seedling discoloration, wilt, and mortality. Typically occurs in late summer or early fall when soils are hot and and dry. Stress-related. Often occurs in nurseries in association with reduced irrigation or root pruning performed to "harden off" seedlings. Known also in plantings, especially on recently coverted agricultural croplands. Minute (< 12 mm) black granules called microsclerotia often visible beneath cortex of moribund seedlings on larger roots, lower stem, and root collar. Often more damaging on droughty, well-drained sands.	Fumigate nursery soils with methyl bromide. Formulations with 33% chloropicrin preferred. Fungicide drenches are less effective than soil fumigation. Use 'nonhost' cover crops such as millet, sorghum, or rye. In field plantings, avoid use of infected/infested nursery stock. Consider delaying planting of pines on fields cropped with susceptible hosts such as soybeans, peanuts, and cotton. Scalping of croplands before planting pines appears beneficial.	[14, 79, 122, 131 134, 136]
Black root rot *Fusarium* spp. *Macrophomina phaseolina* (Tassi) Goid. Plant-parasitic nematodes	1–4, 6	*Seed orchards, nurseries and field*: Progressive and debilitating root infections, especially on young seedlings. Primarily a nursery problem, but also known in the field, especially on recently converted agricultural croplands. Seedling stunting and mortality common. Sometimes accompanied by distinctive swelling, blackening, and cracking of cortical tissues on taproots, larger laterals, and lower stems. Loss of feeder roots and short laterals roots is common.	Fumigate nursery soils with methyl bromide. Formulations with 33% chloropicrin preferred. Certain fungicidal soil drenches may be useful in nurseries. Consider crop sequences and rotation when planting agricultural fields recently growing crops prone to favor buildup of this complex of pest organisms. (See Charcoal root rot – this appendix.)	[79, 122, 136]
Pythium root rot *Pythium* spp.	1–6	*Seed orchards, nurseries and field*: Stunted, chlorotic seedlings and seedling mortality. Roots discolored (black or brown). Noticeable absence of feeder roots. Known primarily in nurseries, but can occur in the field,	Fumigate nursery soils with methyl bromide and use appropriately labeled fungicides where practicable. Promote good seedbed drainage. No practical field control except site selection and promotion of site	[96]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.3 (continued)

Disease/pathogen	Host[1]	Recognition	Management	References
		especially in association with poorly drained soils and/or periodic flooding.	drainage in high-value plantings.	
Rhizoctonia needle blight *Rhizoctonia* spp. *Ceratobasidium* spp.	1, 3	*Nurseries only*: Damping-off and continuing mortality of longleaf pine seedlings in progressively expanding circular to irregular patches. Infections initiated at base of needles near soil line; water-soaking to reddish-brown discoloration of needle bases. Often associated with sand splash from rain or overhead irrigation. A foliage blight is typical on loblolly pine.	Fumigate nursery soils with methyl bromide. Fall plant seedbeds with longleaf pine. Use fresh, clean seed. Composted bark and wood chips as mulch have proved helpful to lessen disease incidence; Avoid use of pine straw as seedbed mulch. No effective fungicide is available. No field control necessary.	[30, 59, 60, 72]
Tip blight *Phomopsis* sp. *Fusarium subglutinans* (Wollenw. & Reink.) Nelson, Toussoun and Marasas comb. nov. *Leptographium procerum* (Kendrick) M.J. Wingfield = *Verticiclodiella procera* Kendrick *Diplodia gossypina* Cke. =*Lasiodiplodia theobromae* (Pat.) Griff. & Maubl. (See pitch canker, this appendix.)	1, 2	*Nurseries only*: Mortality of terminal 1–5 cm of stems. Typically in flushes associated with conducive environmental factors (e.g., warm wet weather at times of succulent terminal growth). Purple lesions common on affected stems.	Damage apparently minimal. Response to occurrence often unnecessary. Disease primarily a function of succulent growing tips and warm wet weather. Appropriately labeled protective fungicides may be helpful in certain situations.	[123]
Procera root disease *Verticicladiella procera* Kendrick	5	*Seed orchards and field*: Chlorosis and wilting of foliage, resinosis at stem bases, and sometimes a black staining beneath bark of infected trees near groundline. Often associated with poor soil conditions.	Avoid poorly drained sites when planting white pines.	[90, 91]
Damping-off *Phythium* spp. *Phytophthora* spp. *Rhizoctonia* spp. *Fusarium* spp. *Cylindrocladium* spp. *Macrophomina phaseolina* (Tassi) Goid. and other species	1–6	*Nurseries only*: Rapid decay of young, succulent tissues before and after emergence from soil at or near germination. Often worse in association with alkaline soil pH, poor drainage, and temperature extremes. Infected tissues water-soaked, mushy, discolored. Seedlings break and fall over at point of lower stem lesions. Poor seed germination.	Fumigate nursery soils with methyl bromide. Promote good seedbed drainage. Treat seed and/or spray (drench) seedlings and/or seedbeds with appropriately labelled fungicides. Use clean, pathogen-free mulches.	[23, 85]
Needle cast *Lophodermella* spp. *Lophodermium* spp. *Ploioderma* spp. and other species	1–6	*Seed orchards and field*: Rare to nonexistent and generally inconsequential in nurseries and young forest plantations. Can be problematic in Christmas tree plantings. Occurs in seed orchards on older trees, but impact poorly defined. Needles turn red-brown to brown from tips typically in late winter to early spring. By late spring affected needles are completely dead and prematurely cast, often leaving tufts of green needles at branch tips in severe cases. Infections predominate in lower crown portions, but entire crowns may be affected. Individual trees vary in susceptibility; severely affected trees may occur side by side with unaffected trees. Small, black, typically elongate fruiting bodies of the causal	Control not generally recommended due to lack of evidence for serious damage. Protection of newly emerging needles with appropriately labeled fungicides may be warranted in Christmas tree plantings. Genetic resistance exists within *Pinus* spp., but has never been selected for since the disease is generally inconsequential.	[23, 29]

Needle rust *Coleosporium* spp.	1–3	*Seed orchards and field*: Unknown in southern pine nurseries. Occurs sporadically in young pine plantings. Most conspicuous in spring and early summer when white, papery pustules (aecia) erupt from infected pine needles, burst and release yellow-orange spores (aeciospores).	Control usually unnecessary. If desired in Christmas tree plantings or other high value areas provide protection during late summer and fall with appropriately labeled fungicides. Eradication of alternate host species (members of the Compositae, Apocynaceae Convolvulaceae, and Campanulaceae) near susceptible pines may be useful to reduce levels of local inoculum.	[108, 133]
Annosus root rot *Heterobasidion annosum* (Fr.) Bref. =*Fomes annosus* (Fr.) Karst.	1–6	*Seed orchards and field*: Unknown in nurseries. Decline and mortality of seedlings and trees almost exclusively in association with stumps and roots of harvested conifers. Resin-soaking of woody roots followed by white stringy rot in advanced stages of disease development. White to brown sporophore initials ("button conks") may occur on roots and root collars of smaller seedlings/trees. Sporophores are leathery, irregularly shaped, brown on top, white with pores beneath and typically occur in the duff layer at the bases of infected stumps and larger trees. Can be serious on residual trees in thinned plantations. Occurs, but generally inconsequential in regenerated plantations. Occurs in seed orchards often in relation to root injury resulting from operations such as subsoiling.	Preventive action includes delaying of replanting pines on problem or high hazard sites, (e.g., deep, well drained, alkaline sands) following harvests, removal of stumps and roots during site preparations (especially applicable to replanting in seed orchards where losses have occurred), and/or treatment of stumps with borax during harvest of non-diseased stands and treatment with the competitively antagonistic saprophytic fungus, *Phlebia gigantea* (Fr.) Donk, is preferred in situations where *H. annosum* is already established.	[2, 7, 69, 88, 133]
Pitch canker *Fusarium subglutinans* (Wollen. & Reink.) Nelson, Toussoun and Marasas comb. nov.	1–6	*Seed orchards, nurseries, and field*. Fungus damages female flowers (strobili), mature cones, seed and trees in seed orchards. Flowers and conelets are killed; mature cones are misshapen, smaller than normal, and often have a purple discoloration. Some cones display necrotic tips with internal resin pockets and external resinous lesions. Seeds are partially to fully destroyed. Tree infections typically are expressed via shoot dieback and bleeding, resinous cankers on stems and branches. Stem infections are often associated with mechanical shaker wounds in seed orchards. Insect/injury associations are common (Fig. 20.3).	Insect control (see Appendix A20.1, this chapter), avoidance of injuries, judicious applications of fertilizers (e.g., avoid unnecessary, excessive, or improper fertilization), and sanitation (e.g., pruning and destroying infected branches, etc.) are key seed-orchard controls. These practices are also key for avoidance of losses in nurseries via infected/contaminated seedlots. No efficacious fungicidal controls are known; rogue infected seedlings. In the field, control is based on good silvicultural practices. Genetic resistance to pitch canker is known in some *Pinus* spp.; this may become a primary means of reducing loss.	[11, 17, 19, 20, 53]
Brown-spot needle blight *Mycosphaerella dearnessii* Barr (= *Scirrhia acicola* [Dearn. Siggers])	3	*Seed orchards, nurseries, and field*. Distinct brown spots on needles; spots typically bordered by yellow bands ('halos'). Needle necrosis distal to infections in advanced stages of development. Small, black, often elongated fruiting bodies of the pathogen may occur on necrotic needle tissues. Rarely severe or problematic on larger trees; particularly severe on grass-stage seedlings.	Provide protection in nurseries with appropriately labeled fungicides throughout infection periods (ca. May-October; longer if temperature and rainfall favor fungus development). Protect outplanted seedlings with registered benomyl root dip. Reduce inoculum potential and disease in young plantations with carefully applied prescribed burns.	[81, 82, 83, 117]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand.

Appendix A20.3 (continued)

Disease/pathogen	Host[1]	Recognition	Management	References
Fusarium root rot *Fusarium* spp. especially: *Fusarium solani* (Mart.) Appel & Wollenw. emend. Synd. & Hans. *Fusarium oxysporum* Schlecht. emend. Synd. & Hans. *Fusarium subglutinans* (Wollenw. & Reink.) Nelson, Tossoun and Marasas comb. nov.	1–6	*Seed orchards, nurseries, and field*: Feeder root necrosis and dysfunction especially in seedlings and young trees. Seedling stunting and mortality. Sometimes associated with poor soil drainage and/or physical/mechanical (insect, nematode, human, etc.) injury. Resin-soaking of larger roots sometimes present. (See black root rot and pitch canker, this appendix.)	Fumigate nursery soils with methyl bromide. Emphasize good seedbed management. Be careful with nitrogenous fertilizers; excessive amounts may exacerbate problem. (See black root rot and charcoal root rot, this appendix.)	[80]
Cylindrocladium root rot *Cylindrocladium* spp. especially: *scoparium* Morgan *C. floridanum* Sobers & Seymour *C. crotalariae* (Loos) Bell & Sobers comb. nov.	5	*Nurseries only*: Stunting and mortality of seedlings. Lateral and primary root necrosis. Blackening and sloughing of root cortex in advanced stages of development.	Fumigate nursery soils with methyl bromide. Formulations with 33% chloropicrin preferred. Use non host cover crops such as corn and grasses; avoid soybeans, alfalfa, clover, and and others. Avoid movement of contaminated soil. Appropriately labeled fungicides may be helpful in certain situations.	[26, 114]
Plant-parasitic nematodes Many species	1–6	*Seed orchards, nurseries, and field*: Stunting and discoloration of young seedlings. Associated also with fungal root infections (see black root rot, this appendix). Largely problematic in unfumigated nursery soils and young plantations on recently converted agricultural fields. Feeder roots may be stunted, necrotic, or discolored and generally unthrifty.	Fumigate nursery soils with methyl bromide. Consider crop rotation sequences and delays before planting pines on known or potentially problematic agricultural croplands.	[126, 127, 128, 129]
Senna seymeria *Seymeria cassioides* (Walt.) Blake (root-parasitic flowering plant)		*Seed orchards and field*: Problematic on certain coastal plain soils, especially where plant populations are high. Plants are "asparagus-like" with tiny scale-like leaves and small yellow flowers produced in the late summer and early fall. Seeds produced in small (ca. 5 mm), shiny brown capsules. Affected seedlings are stunted, chlorotic, and may be killed. *S. seymeria* attaches to host roots by means of distinctive "haustoria" (= irregularly swollen root tissues) which may be observed on the roots of parasitized hosts.	Minimize site preparation on problem sites; *S. seymeria* is favored by bare mineral soils. Prescribed burns may be helpful in severely infected, young pine plantings. Fires should be timed after spring seed germination, but before flowers appear.	[68, 73, 93, 103]
Black seed rot *Lasiodiplodia theobromae* (Pat.) Griff & Maubl. Possibly other species	2	*Seed orchards and nurseries*: Cone and seed infections result in loss of seed and reduced seed quality. Fungus causes tip blights on nursery seedlings (see tip blight, this appendix), and may enter nursery via infected/contaminated seed.	Good seed-orchard management practices are the only practical control. Avoid unnecessary ground contact and excessive cone storage during/after cone harvest.	[101, 138]
Fusiform rust	1–3	*Seed orchards, nurseries, and field*: Infections are	Use genetically improved, rust-resistant planting	[7, 41, 118, 124]

Cronartium quercuum (Berk.) Miyabe ex Shirai f. sp. *fusiforme*		manifest on larger trees by fusoid swellings (galls) on stems and branches. Galls are perennial; characteristic yellow-orange pustules (aecia) produced on surface of active galls in the spring. Spores from aecia (aeciospores) infect newly emerging oak leaves which in turn serve as sources of basidiospores which infect succulent pine tissues during late spring/early summer. Basidiospores released from brown hair-like structures (telia) on underside of oak leaves. Infections on pine nursery stock appear as distinct swellings or knots on stems usually at or near the groundline; sometimes higher on stems. Nursery seedling infections not visible until mid to late fall. *Very serious* on slash and loblolly pines.	stock, especially in seed orchards and plantations in high-hazard rust areas. Minimize site preparation, especially that which promotes oaks, and delay fertilizing stands until ca. age 8 to minimize susceptible pine "target" tissues until trees are beyond the age (or height) where stem infections are serious. Plant alternative, less susceptible species where conditions allow. Inventory at age 5 to determine whether infections warrant carrying or liquidating stands. Protect nursery seedlings with appropriately registered fungicidal seed treatments and seedling sprays.	
Eastern gall rust *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *virginianae* and *C. quercuum* (Berk.) Miyabe ex Shirai f. sp. *echinatae*	4, 6	*Seed orchards and field*: May occur in nurseries, but rarely seen. Similar in nearly all respects to fusiform rust (this appendix), but galls typically globose to subglobose, sometimes cerebroid, as opposed to fusoid. Impact far less than fusiform rust.	Control strategies essentially the same as for fusiform rust (this appendix), but generally unnecessary except in special cases.	[116]
Southern pine cone rust *Cronartium strobilinum* (Arth.) Hedge. & Hahn	2, 3	*Seed orchards and field*: Infected first-year female strobili (conelets) swell, display a reddish discoloration, and exude a sweet pycnial fluid (rust pycniospores produced by pathogen) which often attracts nectar-loving insects. By April, infected conelets are 2–4 times larger than normal. In late spring (April–June) infected conelets support large masses of powdery, yellow-orange aeciospores which are visible at long distances and diagnostic.	Cones and seed may be protected with appropriately labeled fungicides from time of strobilus emergence until scales close following pollination. Evergreen oaks which serve as alternate hosts and provide telial/basidiospore inoculum should be mowed or treated with herbicides in and around seed orchards and seed production areas.	[95, 100, 102]
White pine blister rust *Cronartium ribicola* J. C. Fisch. ex Rabenh.		*Seed orchards and fields*: Conspicuous lesions (cankers) on branches and stems; may result in branch loss. Basidiospores from alternate hosts (*Ribes* spp., gooseberry, currant) infect pine needles in fall; fungus grows into branches and stems and produces cankers. Pycniospores in amber-colored droplets produced 2–4 years later. Yellow aecia, with aeciospores, develop in spring (1 year later) as blisters on canker surfaces. Windborne aeciospores infect *Ribes* in surrounding areas. Infected *Ribes* produce urediniospores which infect other *Ribes* through the summer. In fall, hair-like telia produce teliospores which germinate to produce basidiospores.	Eradicate alternate hosts within 150–300 m of around a planting site. Hazard rating zones have been identified for some areas. High hazard: use genetically resistant stock or do not plant white pine; low hazard: no control necessary. In seed orchards, prune branches with cankers > 15 cm from stem. Provide protection in young seed orchards or other high value areas with appropriately labeled fungicides.	[5, 6, 23, 115, 133]

[1] Host pines: 1 = loblolly; 2 = slash; 3 = longleaf; 4 = shortleaf; 5 = white; 6 = sand

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