Regeneration Insect Pests: Protecting Southern Pine Seedlings After Outplanting

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Abstract

The intensively managed plantations of genetically improved pine (*Pinus* sp.) in the Southern United States have a low threshold for insect damage. Research has refined integrated pest management options for these insect pests of young pines. Timing of foliar applications to control the Nantucket pine tip moth (*Rhyacionia frustrana* [Scudder in Comstock]) is simplified by published optimal spray period predictions for all Southern States. Pales weevil (*Hylobius pales* [Herbst]) and pitch-eating weevil (*Pachylobius picivorus* [Germar]) are managed by adjusting planting schedules. New pesticides and application technologies are also available, such as synthetic pyrethroids for tip moth, weevils, and sawflies. Alternatives for tip moth management include a tablet formulation of imidacloprid and the biorational spinosad. Systemic neonicotinoids are labeled for white grubs, aphids, and scale insects, as are the biorational avermectins for spider mites. Fipronil can be applied to containerized seedlings in the nursery, as well as at planting. This paper was presented at the Joint Meeting of the Northeast Forest and Conservation Nursery Association and Southern Forest Nursery Association (Lake Charles, LA, July 18–21, 2016).

Figure 1. A healthy first-season progeny test of loblolly pine in South Carolina, an example of intensive forestry in the South. (Photo by Steve McKeand, North Carolina State University, Tree Improvement Cooperative, 2006)

Introduction

The large industrial forest plantations of the South produce more timber than any other region of the world. Virtually all of the intensively managed pine plantations in the Southern United States are comprised of genetically improved planting stock from tree improvement programs (figure 1); more than 95 percent are genetically improved loblolly pine (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm.) (McKeand et al. 2003). Seedling costs range from $25 to $200 per ac ($62 to $494 per ha), although elite, genetically improved loblolly pine seedlings are typically under $100 per ac ($247 per ha) (McKeand et al. 2010). When site preparation and other management costs are added, these plantations represent a major investment on a per-ac basis, thereby resulting in a great incentive to optimize survival and growth.

Insects can directly damage young pines or cause unthrifty growth. Fortunately, in the last 20 years, integrated pest management (IPM) programs have provided effective management options. This article describes some of the most important insect pests of southern pine seedlings and the effective management options to address them.

Southern Pine Insect Pests

Nantucket Pine Tip Moth

Nantucket pine tip moth (*Rhyacionia frustrana* [Scudder in Comstock]; Lepidoptera: Tortricidae) is the major insect pest of pine regeneration in the South (Asaro and Creighton 2011). This pest infests young pine plantations, tree improvement progeny tests, and Christmas tree plantations throughout the Eastern and Southern United States. Loblolly pine, shortleaf pine (*Pinus echinata* Mill.), and Virginia pine (*P. virginiana* Mill.) are the most commonly infested, whereas longleaf pine (*Pinus palustris* Mill.) and slash pine are only occasionally affected (Fettig et al. 2000, Nowak et al. 2010).

The Nantucket pine tip moth is primarily a pest of seedlings and young trees; attacks on older trees are not numerous, and the pests have little impact on trees older than 6 years of age. Infestations are most common and severe in the first or second year of plantation establishment. Larval feeding kills the terminal buds and tips of shoots, and the attached needles turn reddish brown (figure 2). Attacks are most common on the terminal leader (figure 3) and upper branches but all shoots can be infested (Nowak et al. 2010).

Stunting and deformation of trees occurs with resulting growth reduction. The height and volume growth lag delays rotation periods, which impedes the ability of managers to grow merchantable trees in the shortest time through intensive management (Nowak et al. 2010).

Adult moths are 4 to 7 mm (0.2 to 0.3 in) long and have forewings of red scales scattered among bands of gray scales (figure 4). Mated females deposit clusters of eggs on needles and shoots. Of the five larval instars, the first instar larvae enter needles and feed within, as do the second and third instars. The later instars are 9 to 10 mm (0.35 to 0.40 in) long yellow-red larvae and feed within the buds and shoots, consuming the vascular cambium and killing the bud or shoot. Pupation occurs in the damaged tip. Pupae are brown in color, about 6 mm (0.25 in) long, and overwinter in shoot tips (Asaro et al. 2003, Nowak et al. 2010).

Figure 2. A pine seedling severely infested with Nantucket pine tip moth (*Rhyacionia frustrana* [Scudder in Comstock]). (Photo by R. Scott Cameron, Advanced Forest Protection, Inc., Bugwood.org)

Figure 3. Damage to growing pine branch caused by larvae of the Nantucket pine tip moth (*Rhyacionia frustrana* [Scudder in Comstock]). (Photo by Ronald F. Billings, Texas A&M Forest Service, Bugwood.org)

The Nantucket pine tip moth has 2 to 5 generations per year depending on climate and location. The life cycle is synchronized roughly with host phenology so that a new generation of adults emerges with each new growth flush of the young trees (Asaro et al. 2003, Fettig et al. 2000). In spring, first-generation adults emerge in large numbers within a definite interval;

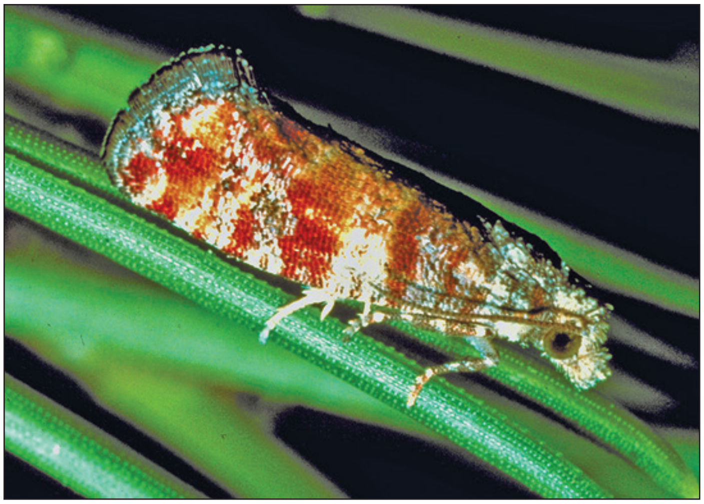

Figure 4. An adult Nantucket pine tip moth (*Rhyacionia frustrana* [Scudder in Comstock]) on pine needles. (Photo by James A. Richmond, USDA Forest Service, Bugwood.org)

later generations are smaller and less discrete, as life stages tend to overlap as the season progresses (Asaro and Berisford 2001, Asaro and Creighton 2011).

Tip moth infestations have become more prevalent since the adoption of intensive plantation forestry and genetically improved planting stock. Since the 1990s, researchers have investigated new techniques for hazard-rating and management (Asaro et al. 2003). One technique is to use degree-day models (Berisford et al. 1984; Gargiullo et al. 1984; Richmond 1992) to schedule foliar applications to coincide with the presence of exposed early-instar larvae as they move among the needles (Asaro et al. 2003). These models, however, are labor-intensive; proper use requires monitoring of traps, collection of daily maximum and minimum temperature data, and calculation of degree-days. Mistakes in predictions often occur due to improper model use (Fettig et al. 2000).

An alternative to the degree-day models is to use predicted optimal spray periods. A manager can locate the nearest weather station to the plantation site and use the optimal spray periods in the appropriate publication to time insecticide applications (Fettig et al. 2000—Southeastern States, Fettig et al. 2003—Western Gulf States). Control of the large, synchronous first generation has the greatest impact; timing this application is critical for effective management (Fettig and Berisford 2002). These field-validated predictions work for synthetic pyrethroids (bifenthrin, esfenvalerate, lambda-cyhalothrin, and permethrin) currently registered for tip moth control (Dalusky and Berisford 2002, Fettig et al. 2000). These products have largely replaced the organophosphate products still registered for tip moth control (Nowak et al. 2000).

Biorational pesticides registered for tip moth control include diflubenzuron and tebufenozide, both growth regulators; spinosad, a biopesticide derived from bacterial fermentation; and the microbial *Bacillus thuringiensis* variety *kurstaki* Berliner (Btk). Nowak et al. (2000) demonstrated the efficacy of spinosad and Btk and established spray-timing intervals for the Georgia Piedmont area. These biorationals are less harmful to parasitoids and other beneficial insects than the pyrethroids. Spinosad, with its very low worker-exposure risk, is a valuable addition to tip moth IPM (Nowak et al. 2000).

Systemic insecticides eliminate the problem of timing applications (Berisford et al. 2013). Two systemics are registered for tip moth control, CoreTect™ Tree and Shrub Tablets (formerly SilvaShield™ Forestry Tablets; Bayer Environmental Science) and PTM™ Insecticide (BASF Corporation). The CoreTect™ Tablet is a formulation of 20 percent imidacloprid plus a small amount of fertilizer (12-9-4). The tablet can be placed into the planting hole when the seedling is planted or pushed into the ground near the seedling after planting. PTM™ Insecticide is a 9.1-percent formulation of fipronil that must be diluted and applied using a commercially available soil injector. Application can be made into the planting hole or below ground within the root zone of each seedling. This product can also be applied to containerized seedlings in the nursery.

Both PTM™ and CoreTect™ reduce tip moth numbers during the first 36 months after planting—the critical period in which tip moth impact can be the greatest (Asaro and Creighton 2011, Grosman 2010). Both products have relatively low toxicity and are labeled as general use pesticides. They can be applied at any time when the soil is not frozen (Grosman 2010). Labels restrict the amount of product per ac per year to 21 fl oz (0.6 L) of PTM™ formulation and 450 CoreTect™ tablets; managers must account for the number of seedlings per ac. Cost is perhaps the major disadvantage to systemics. At roughly $100 per ac for either product, plus the added application costs, systemics are a substantial addition to already costly intensive silvicultural practices (Asaro and Creighton 2011).

Figure 5. Pales weevil (*Hylobius pales* [Herbst]), feeding damage on the stem of a young pine seedling. (Photo by Lacy L. Hyche, Auburn University, Bugwood.org)

Figure 6. A pitch-eating weevil (*Pachylobius picivorus* [Germar]), feeding on a pine stem. (Photo by Robert L. Anderson, USDA Forest Service, Bugwood.org)

Reproduction Weevils

The pales weevil (*Hylobius pales* [Herbst]) and the pitch-eating weevil (*Pachylobius picivorus* [Germar]) (Coleoptera: Curculionidae), commonly known as reproduction weevils, are important pine regeneration pests in the South (Cade et al. 1981, Grosman et al. 1999), especially in recently cutover stands that are replanted to pine. Volatile chemicals released by cut pine stumps and slash attract weevils. The weevils breed and emerge in large numbers then move to the pine seedlings to feed on the bark. This feeding girdles the stem and kills the seedling. Maturation feeding by brood beetles causes the most damage (Cade et al. 1981) (figure 5). First-year seedling mortality is often 30 to 60 percent but can reach 90 percent (Grosman et al. 1999); this loss is unacceptable in modern intensive plantation forestry.

Similar in appearance, adults of both species have broad snouts and clubbed elbowed antennae (figure 6). The pales weevil and the pitch-eating weevil are both robust, dark-brown to black with irregular patches of yellow scales on the thorax and elytra; the pitch-eating weevil is typically slightly darker (Antonelli 2012b, Nord et al. 1984). Females lay eggs on underground parts of stumps, roots, and slash. Larvae, legless white grubs with a brown head capsule, feed between phloem and wood. There are five larval instars. The mature larva, about 12 mm (0.5 in) in length, excavates a chamber, packs the excavated wood fragments around itself, and pupates in this "chip cocoon" (Nord et al. 1984).

In the Piedmont and Coastal Plain of the South, adult weevils are active throughout the year. Except for the coldest winter months, adults quickly find freshly logged areas and begin to reproduce. The life cycle varies from 3 to 12 months in this area, depending on when the logged areas are colonized. In the southern Appalachians, the life cycle cannot be completed in a year; larvae overwinter, and adults emerge the following spring (Nord et al. 1984).

Weevils are managed by silvicultural practice. Planting dates are adjusted to exploit the life cycle of the insects. In the Piedmont and Coastal Plain, stands logged and site-prepared before July can be planted during the following winter without weevil damage because the emerging brood weevils will disperse before the planting time. Planting should be delayed 1 year for stands logged in July or later (Cade et al. 1981, Grosman et al. 1999, Nord et al. 1984). In the southern Appalachians, planting must be delayed by 1 or 2 years (Nord et al. 1984).

High-value sites, such as breeding program progeny tests and Christmas tree plantations, need careful monitoring and merit additional care, such as grinding stumps and removing slash.

Stands logged late in the year must, on occasion, be planted in the same year due to financial or management constraints. In the Appalachians, where weevils take longer to disperse, waiting more than a year to regenerate may be impractical (Nord et al. 1984). These plantings need monitoring and, if necessary, chemical control. Stumps can be treated prior to planting seedlings. Insecticide application to seedlings can be done if weevil damage is evident. Registered insecticides include bifenthrin, esfenvalerate, and permethrin (synthetic pyrethroids); and phosmet (organophosphate).

Managers should assess the potential for weevil damage. Former old-field and hardwood sites are low hazard; they will not attract weevils when cut. Extensive clearcuts of pine, especially adjacent to cuts made the year before, are high hazard; they will likely have high weevil numbers (Nord et al. 1984).

Pine Sawflies

In the South, the redheaded pine sawfly (*Neodiprion lecontei* [Fitch]; Hymenoptera: Diprionidae) is often a major pest of young pine plantations. Shortleaf, loblolly, slash, and longleaf pines are all prone to being attacked (Wilson and Averill 1978).

The redheaded pine sawfly overwinters as a prepupa in a silken cocoon in litter under the trees. Adults emerge in the spring, and larvae feed gregariously on needles before dropping to the ground. In the South, several generations per year occur, and generations may overlap. Larvae feed together, stripping the needles off a branch before moving to another (figure 7). When a tree is defoliated, larvae move to adjacent trees to feed until they are fully grown. Young larvae have a brown, transparent head, and older larvae have a characteristic shiny red head and two to four rows of black spots on a yellow body (figure 8) (Wilson and Averill 1978).

Controlling sawflies is usually unnecessary in large plantations. Outbreaks typically subside after a year or so due to parasitoids and diseases. Small mammals consume cocoons on the ground (Wilson and Averill 1978). Control may be needed in progeny tests, young orchards, and other high-value sites where the damage threshold is low. In those cases, diligent monitoring in early spring will reveal populations before damage is extensive. Contact insecticides labeled for sawfly

Figure 7. A young plantation of longleaf pine (*Pinus palustris* Mill.) defoliated by the redheaded pine sawfly (*Neodiprion lecontei* [Fitch]). (Photo by Andrew J. Boone, South Carolina Forestry Commission, Bugwood.org)

Figure 8. Larvae of the redheaded pine sawfly (*Neodiprion lecontei* [Fitch]), feeding on pine needles. (Photo by Gerald J. Lenhard, Louisiana State University, Bugwood.org)

control include acephate and malathion (organophosphates); carbaryl (carbamate); bifenthrin, cyfluthrin, lambda-cyhalothrin (synthetic pyrethroids); diflubenzuron and spinosad (biorationals). The systemic imidacloprid, as CoreTect™ Tree and Shrub Tablets, is also labeled for sawfly control and is an IPM option.

White Grubs

The beetle genus *Phyllophaga* (Coleoptera: Scarabaeidae), known as May or June beetles, have soil-inhabiting larvae called white grubs (figure 9). The larvae feed on organic matter and plant roots as they develop (Mayfield 2012); however, they can also feed on the roots of young trees in nursery and plantation settings. They are abundant in grassy, old field sites that have been fallow for some time. Coniferous plantations established on or near these habitats are the most severely impacted (Speers and Schmiege 1971).

Symptoms are similar to drought damage; in late summer and early fall, pine seedlings turn red or brown and may die (figure 10). Seedlings are easily uprooted with a gentle pull and reveal clipped or girdled roots. Excavation exposes large (up to 4.5 cm [1.8 in]), white, C-shaped larvae with brown heads and a translucent, swollen terminal abdominal segment. Pupae resemble adult beetles. (Mayfield 2012, Speers and Schmiege 1971).

Figure 9. White grub (*Phyllophaga* spp.) larvae exposed after feeding on pine roots. (Photo by Steven Katovich, USDA Forest Service, Bugwood.org)

Figure 10. A pine seedling killed by larvae of *Phyllophaga* spp. feeding on roots. (Photo by Steven Katovich, USDA Forest Service, Bugwood.org)

Management includes preplanting excavation to sample for larvae, particularly for sites being converted from agricultural use. Site preparation should include disking several times from late spring through fall when larvae are near the surface. Fumigation is problematic; larvae deeply imbedded in cold months may escape (Mayfield 2012). If damage is observed post-planting, insecticides may be applied. Several brands of the systemic imidacloprid are registered for white grubs, including CoreTect™ Tree and Shrub Tablets.

Aphids and Scale Insects

Aphids and scale insects, both in the order Homoptera, are occasional pests on young pine seedlings. Both groups feed by sucking plant juices with piercing-sucking mouthparts (Antonelli 2012a).

Aphids in the genus *Cinara* (Homoptera: Aphididae) are the most common aphids on pines. They are large, long-legged, darkly colored, pear-shaped aphids found on the stems of terminal and lateral branches (figure 11). Infestations rarely kill trees; large numbers of aphids may reduce vigor. When feeding, aphids secrete sweet, sticky honeydew that accumulates on needles and stems (Brooks and Warren 1964) and attracts bothersome bees and ants (Clarke 2010). Sooty mold fungi grows on honeydew; it gives trees an unthrifty appearance and

Figure 11. Giant conifer aphids (*Cinara* spp.) feeding on pine branches in the "candle" stage in spring. (Photo by Jim Baker, North Carolina State University, Bugwood.org)

interferes with photosynthesis. Natural enemies usually keep aphids in check (Antonelli 2012a) Severe infestations can be treated with imidacloprid or thiamethoxam (neonicotinoids), pymetrozine (avermectin), or acephate (organophosphate).

Scale insect (Homoptera) (table 1) infestations reduce growth and vigor of young trees; severe infestations can kill young seedlings (figure 12) (Clarke 2010, 2013). As with aphids, scale insects produce honeydew; infestations are accompanied by the resulting sooty mold, bees, and ants (figure 13).

Table 1. Common scale insect (Homoptera) species on southern pines.

Soft Scales—Coccidae	
	Wooly Pine Scale—*Pseudophilippia quaintancii*
	Pine Tortoise Scale—*Toumeyella parvicornis*
	Virginia Pine Scale—*Toumeyella virginiana*
Mealybugs—Pseudococcidae	
	Loblolly Pine Scale—*Oracella acuta*
Armored scales—Diaspididae	
	Pine Needle Scale—*Chionaspis pinifoliae*
	Pine Scale—*Chionaspis heterophyllae*

Figure 12. Pine tortoise scale (*Toumeyella parvicornis* [Cockerell]) feeding on the stem of a pine tree. (Photo by USDA Forest Service, Northeastern Area Archives, Bugwood.org)

Figure 13. A young pine infested with pine tortoise scale (*Toumeyella parvicornis* [Cockerell]) and covered with sooty mold growing on honeydew produced by the scale insects. (Photo by Lacy L. Hyche, Auburn University, Bugwood.org)

Scale insects often occur as secondary pests after insecticide applications for other pests also kill off natural enemies; pyrethroid products are notable for causing outbreaks (Clarke 2010). When outbreaks occur, managers should adjust management and, if feasible, pesticide use should be avoided to enable natural enemies to build up (Clarke 2010). Severe infestations can be treated with acephate or malathion (organophosphates); or acetamiprid (neonicotinoid). For efficacy, foliar applications must be timed when the crawler stage is present and be applied as drenching sprays rather than aerosols. Dormant oils are also effective (Clarke 2010, 2013).

Mites

The spider mites (*Oligonychus* spp.; Acari: Tetranychidae) infest young pines (figure 14). Spider mites use their needle-like mouthparts to pierce plant cells and suck out the cell contents, resulting in a mottled appearance of the needles. Eventually, needles turn yellow or brown (figure 15). Associated with the discolored needles is a dense webbing made by the mites (Mangini 2012).

Spider mites and rust mites have natural enemies that keep their populations in check; the most important biological control agents are the phytoseiid mites (family Phytoseiidae). Chemical control is usually not needed. Miticides available for severe infestations are abamectin and spiromesifen (avermectins). Insecticidal soaps and dormant oils are also effective (Mangini 2012).

Figure 14. Spruce spider mite (*Oligonychus ununguis* [Jacobi]) adult and egg on conifer needle. (Photo by USDA Forest Service, Northeastern Area Archives, Bugwood.org)

Figure 15. Fir tree with discolored needles caused by spruce spider mite *(Oligonychus ununguis* [Jacobi]) feeding. (Photo by USDA Forest Service, Northeastern Area Archives, Bugwood.org)

Southern Pine Seedling IPM

Intensively managed pine plantations, progeny tests, and young seed orchards are major investments. A solid IPM program for regeneration insects will protect these investments by planning for problems before the trees are planted. Managers must consider the array of potential pests and their biology, site-specific conditions, damage thresholds, and logistic and financial constraints to develop an optimal management plan.

Some pests, such as Nantucket pine tip moth, are widespread and can be expected at any plantation site in the South. Sawflies, in contrast, occur sporadically in space and time. An IPM plan must be flexible enough to handle both. In all cases, monitoring is crucial—this is the heart of regeneration IPM. Finding an infestation early, before damage is extensive, is the goal. Early detection usually results in better control efficacy and efficiency; early-instar larvae are more easily controlled than large larvae or adults.

Effective IPM includes the judicious use of pesticides. Managers should use a product that is labeled for the site and/or pest species involved. Label directions must be followed—a central tenet of IPM is to avoid mistakes when handling pesticides and making applications. Managers should insist that contractors make pesticide applications correctly.

Insect pest management can be a useful part of intensive forestry in the South. With this discussion and the abundant resources available online (table 2), regeneration insect IPM for southern pine seedlings can be done effectively and efficiently.

Table 2. Online resources for regeneration insect biology, management, and pesticide information.

Resource	Website	Comments
General references		
Forest Nursery Pests—USDA Ag. Hdbk. 680	http://www.rngr.net/publications/forest-nursery-pests	General reference on nursery insects and diseases of conifers and hardwoods—each chapter can be downloaded as individual document
Link to Forest Insect and Disease leaflets	https://www.na.fs.fed.us/pubs/	Leaflets provide biological and management information on various forest insect and diseases
Tip moth references		
Fettig et al. (2000)	http://www.srs.fs.usda.gov/pubs/rp/rp_srs018.pdf	Optimal spray predictions for AL, FL, GA, MS, NC, SC, and VA—foliar applications for tip moth control
Fettig et al. (2003)	http://www.srs.fs.usda.gov/pubs/rp/rp_srs032.pdf	Optimal spray predictions for AR, LA, and TX—foliar applications for tip moth control
Asaro et al. (2003)	http://www.srs.fs.usda.gov/pubs/ja/ja_asaro005.pdf	Comprehensive literature review of publications on Nantucket pine tip moth—through 2002
Nowak et al. (2000)	http://www.bioone.org/doi/pdf/10.1603/0022-0493-93.6.1708	Optimal spray timing for applications of lambda-cyhalothrin, spinosad and Bacillus thuringiensis variety kurstaki Berliner (Btk) in southern Piedmont, NC and coastal VA
Nantucket pine tip moth Forest Insect and Disease leaflet	http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev2_042974.pdf	Biology and management information for Nantucket pine tip moth
Pesticide label information		
Crop Data Management Systems, Inc. (CDMS®)	http://www.cdms.net/Home.aspx	Listings of pesticide manufacturers, labels, and Safety Data Sheets (SDS)
Environmental Protection Agency (EPA) Pesticide Product and Label System	http://iaspub.epa.gov/apex/pesticides/f?p=PPLS:1	Listings of past and current registrations for pesticides
Greenbook®	http://www.greenbook.net/	Listings of pesticide manufacturers, labels, and SDS
Kelly Solutions®	http://www.kellysolutions.com/	Web portal for State Department of Agriculture Registrants and Licensees
National Pesticide Information Retrieval System (NPIRS)	http://ppis.ceris.purdue.edu/	Web listings of Federal pesticide registrations
National Pesticide Information Center	http://npic.orst.edu/index.html	Pesticide information and links to resources

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