SOUTHERN GROUP OF STATE FORESTERS

# Policy Adopted by the SGSF April, 2015
# FOREST HEALTH ISSUES AFFECTING SHORTLEAF PINE

**SOUTHERN GROUP OF STATE FORESTERS STATEMENT**

Although loblolly and slash pine have been the preferred tree species planted in the South since the 1930s, today's landowners should also consider shortleaf pine as a valid choice for reforestation and restoration projects. On sites other than heavy Piedmont soils, where littleleaf disease may be a problem, shortleaf pine performs well and experiences forest health risks comparable to those of loblolly pine. When the ecological benefits of a well-managed shortleaf stand align with a landowner's forest management objectives, shortleaf pine warrants consideration as a species to plant.

**SHORTLEAF PINE KNOWLEDGE GAPS/RESEARCH NEEDS IDENTIFIED**

Much of what is known about the resistance of shortleaf pine to damaging agents is based on empirical observations and is not well documented in the scientific literature. There is a need to fill knowledge gaps related to potential impacts of such factors as invasive pests, pine tip moths and littleleaf disease under future conditions related to climate change. Genetic resistance traits to incorporate into future shortleaf pine breeding programs also should be investigated.

## INTRODUCTION

Shortleaf pine, *Pinus echinata*, is the most widely distributed pine native to the southern United States. It can be found in 22 states from New Jersey to Florida and west to eastern Texas. However, its domain is diminishing. Between 1980 and 2010, the area of shortleaf pine-dominant forests declined 52%, from 12.6 million acres to 6.1 million acres.

Although changing land use is responsible for the largest proportion of shortleaf pine ecosystem loss, afforestation and reforestation efforts have favored the use of loblolly pine over shortleaf pine, largely because of the economic advantages resulting from faster growth and shorter rotation lengths. However, this fiber production model fails to consider the lower susceptibility of shortleaf pine to mechanical damage from fire, ice or wind, resistance to insects or diseases, or potential premiums from tighter-grained grade materials (for a detailed list of risk comparisons among southern pines, see Table 1).

Shortleaf pine may be the species of choice where suitable soil and site conditions exist and the landowner's management objectives are not limited to just fiber production. For example, on the right sites, shortleaf pine may be the logical species to plant to maintain biodiversity, to favor pine-hardwood mixtures and improve wildlife habitat, to maintain forest cover over a longer rotation, or to restore historical forest conditions in local areas.

Shortleaf pine landscapes represent an extraordinary diversity of cultural, ecological, and economic values centered on water quality, wildlife, recreation, and a high-value wood products industry. With millions of people depending on the values and benefits of this imperiled ecosystem, the development of a range-wide conservation strategy has begun.

With the inception of the America's Great Outdoors (AGO) Initiative in 2010, significant attention is being directed toward the restoration of landscapes identified as being imperiled by the presence of population growth and expanding development. For the member states of the Southern Group of State Foresters (SGSF), success was previously achieved with America's Longleaf Restoration Initiative as one of the five inaugural programs of the AGO. Attention has now shifted towards restoring the shortleaf pine ecosystem.

Because the majority of shortleaf pine restoration efforts will take place on non-industrial private lands, a shortleaf pine advocate must be able to effectively communicate with landowners the forest health considerations specific to shortleaf pine restoration. The SGSF Forest Health Committee prepared this summary of forest health issues related to this species to address uncertainties regarding its establishment. The following materials represent generalized knowledge about shortleaf pine that addresses insects, diseases, abiotic factors, silviculture, tree improvement, and nursery practices.

## FOREST INSECT PESTS

Growth and survival of shortleaf pines may be affected by destructive insect pests at all stages of tree development (Table 2).

<u>Cone and Seed Pests:</u> As with all southern pines, cones and seeds of shortleaf pine produced in commercial seed orchards are subject to losses from a variety of coneworms and seed bugs during their two-year developmental period. **Coneworms** of the genus *Dioryctria* (primarily *D. amatella*) may cause extensive losses to shortleaf pine cones and seeds in orchards not regularly treated with insecticides. These insects have several generations per year, requiring multiple applications of insecticide sprays. A recently-registered, restricted use systemic insecticide containing the active ingredient emamectin benzoate (sold by Arborjet, Inc., under the trade name TREE-äge™) has provided extended protection of cone crops (up to six years with a single application). Two species of **seed bugs** (*Leptoglossus corculus* and *Tetyra bipunctata*)

also may destroy seeds with their sucking mouthparts. These insects are more difficult to control with systemic insecticides and most seed orchard managers rely on repeated topical sprays of registered insecticides to reduce losses.

Nursery Pests: Occasionally, pine seedlings in east Texas and western Louisiana have suffered defoliation from the native **Texas leafcutting ant**, *Atta texana*. These leafcutting ants harvest vegetation, including pine needles and buds, which they use to cultivate a fungus within large underground colonies. These colonies are most common in deep, sandy soils. Damage is most severe in winter months when no broadleaf foliage is available. Ant colonies located near nursery beds can be eliminated with chemical insecticide treatments (PTM® (fipronil) or Amdro® Ant Block (hydramethylnon)).

Seedling (1 -5 years old) Pests: **Pales weevil** (*Hylobius pales*) and other regeneration weevils such as the **deodor weevil** (*Pissodies nemorensis*), and the **pitch-eating weevil** (*Pachylobius picivorus*) can cause considerable losses to shortleaf pine seedlings. Adult weevils reproduce in freshly cut stumps or weakened trees. Losses tend to be localized in scattered tracts and are particularly common if tracts of timber are replanted within six to nine months of late summer or fall harvests. Adults remove patches of bark from the stems, branches or roots, mostly in the spring, and affected seedlings often die. While seedlings can be protected with insecticides, a more economical option is to delay planting on sites harvested after June 1 for six to nine months. Sites harvested from December to June can be planted the following winter.

In east Texas and western Louisiana, the **Texas leafcutting ant** may eliminate newly planted pine seedlings near colony sites. Elimination of the colony with an insecticide application may be required prior to planting to avoid losses.

The **Nantucket pine tip moth** (*Rhyacionia frustrana*) is a major pest of young, plantation-grown shortleaf pines. Larvae bore into the leader and branch tips, resulting in stunted growth or deformed stems. Larvae also may feed on shortleaf female flowers and pine conelets in seed orchards. Tip moth infestations may cause substantial impacts to the growth and yield of shortleaf and loblolly pines in the first ten years after plantation establishment. Some research has shown that impacts are often short-lived, essentially disappearing by the time the trees attain pulpwood size. Topical insecticide sprays (applied each tip moth generation) and systemic insecticides ( i.e., PTM® containing fipronil) are available to reduce tip moth damage on high risk sites, but benefits may not exceed the costs.

Young Stand (6-20 years old) Pests: The **redheaded pine sawfly** (*Neodiprion lecontei*) and other sawflies of the same genus are important defoliators of natural- and plantation-grown shortleaf pine throughout its range, particularly in young stands. Sawfly larvae feed in large colonies which may rapidly strip young trees of their foliage. Large amounts of frass (excrement) beneath the tree and small, brown cocoons in the humus, soil, or on the needles are signs of a sawfly infestation.

Moderate to heavy defoliation stunts height growth and may cause forking in the upper crown, but seldom kills the affected shortleaf pine saplings. Several generations of sawflies may occur in a single growing season. Sawfly outbreaks are usually controlled by natural enemies, viral diseases, or unfavorable weather. Direct control is seldom warranted.

The most destructive insect pests affecting shortleaf pulpwood stands are pine bark beetles, including the **southern pine beetle** (SPB, *Dendroctonus frontalis*), *Ips* engraver beetles (*Ips* spp.), and the black turpentine beetle (BTB, *D. terebrans*). The most destructive of the five bark beetle species is the southern pine beetle. This insect may cause severe losses by creating infestations that may expand rapidly if not controlled, affecting hundreds of acres. Infestations of SPB (commonly called spots) are most common in overcrowded, unthinned natural stands and plantations. Having three to seven overlapping generations per year, adult beetles may attack trees when ambient temperatures exceed approximately 60° F. Infested trees can be recognized by the fading or red crowns, dime-sized masses of resin (pitch tubes) in bark crevices and, more diagnostically, by the characteristic “S”- shaped galleries filled with frass beneath the bark. State and Federal cooperators annually deploy early season pheromone traps to forecast SPB outbreaks and infestation trends across the South. Protocols also have been established for setting ground check and direct control priorities, since many small infestations will tend to be abandoned by emerging SPB and will need no control. Recommended SPB direct control methods include cut-and-remove (salvage) and cut-and-leave, which disrupt expanding infestations. Periodic thinning of pulpwood and young sawtimber stands and harvesting stands at maturity are the most effective methods to reduce stand susceptibility to SPB infestations.

Three species of native ***Ips*** **engraver beetles** (*Ips calligraphus, I. grandicollis*, and *I. avulsus*) may infest shortleaf pines at all ages beyond the sapling stage. Unthinned stands weakened by drought or individual pines affected by other biotic and abiotic factors, such as insect-caused defoliation, ice, wind, or fire, are particularly susceptible to *Ips* infestations. It is important to distinguish between infestations of *Ips* engraver beetles and those of the more destructive SPB. An individual tree exhibiting discolored foliage at the top of the crown with green foliage on the lower limbs is indicative of an *Ips* infestation. Also, *Ips* pitch tubes are often found on bark plates, unlike those of SPB which are limited to bark crevices. *Ips* beetles make distinct galleries free of frass beneath the bark in form of an “H,” “Y,” or “I,” whereas galleries of SPB are “S”-shaped. *Ips* engraver beetles typically infest a few scattered trees within the stand and seldom establish rapidly expanding, tree-to-tree infestations characteristic of SPB. Direct control, other than the harvest of dead and dying trees where feasible, is seldom required for *Ips* infestations. As with SPB, timely thinning will reduce the incidence of infestations. To reduce the likelihood of *Ips* infestations following thinning, felled trees should be promptly removed from the stand to eliminate favorable breeding material. Precommercial thinning should be limited to the late summer, fall, or winter months to reduce the abundance of favorable breeding material.

The **black turpentine beetle** (BTB, *Dendrodoctons terebrans*) has a range that coincides with that of its major southern pine hosts, including shortleaf pine. However, it is a more frequent pest of longleaf pine (*P. palustris*), slash pine (*P. elliottii*), and loblolly pine (*P. taeda*), rather than shortleaf pine. Attacks of BTB are often found coinciding with other bark beetle attacks or damage from logging operations. Pitch tubes of BTB (about 1 inch in diameter) are larger than those of SPB and *Ips* and are limited to the lower trunk. Galleries are usually in the form of large cavities, with the BTB larvae feeding gregariously beneath the bark. Attacks often do not kill the tree and direct control is seldom warranted. Reducing the number of logging scars to standing pines in thinning operations will reduce BTB attacks in managed stands.

Maintaining vigorously growing trees through vegetative management (i.e., periodic thinning and prompt removal of damaged trees) is the preferred approach to prevention, regardless of the bark beetle species. High-value pines can be protected for two years from SPB, *Ips* engraver beetle, and BTB attacks with injections of the systemic insecticide emamectin benzoate (TREE-äge™), a restricted-use pesticide. This currently is the only insecticide registered for use against southern pine bark beetles in forest situations.

<u>Mature Stand (> 20 years) Pests:</u> The most common insect pests of sawtimber stands of shortleaf pine are **pine bark beetles** and the **blackheaded pine sawfly** (*Neodiprion excitans*). Pine bark beetles are discussed above as pests of pulpwood stands. The blackheaded pine sawfly is one of several species of sawflies that may feed on shortleaf pine. This species prefers to attack mature loblolly and shortleaf pines and may cause complete defoliation. Defoliation *per se* usually doesn't cause tree mortality, but the weakened trees may be more susceptible to attacks from tree-killing bark beetles, such as SPB. The larvae have olive green bodies and shiny black heads and feed in large colonies. Sawfly outbreaks are sporadic, seldom requiring direct control.

<u>Minor Forest Insect Pests:</u> Other insect pests occasionally may be encountered affecting shortleaf pine. These may include **aphids** and **scales**, **pine webworm**, several other species of **pine sawflies**, and **wood borers** and **ambrosia beetles** in declining or dead trees. These insects seldom cause sufficient damage to necessitate direct control. Fortunately, to date no non-native invasive insects have been detected infesting shortleaf pine.

## FOREST DISEASE PESTS

A variety of forest tree diseases common to most southern yellow pines also affects shortleaf pine; however, the risk of extensive damage can be relatively low with modern forestry practices. Littleleaf disease and *Heterobasidion* root disease have the greatest potential for reducing productivity and causing mortality, but potential threats for these can be mitigated by avoiding high-hazard sites and employing sound silvicultural practices.

Littleleaf disease: The most significant disease of shortleaf pine is **littleleaf disease**. In addition to the presence of the pathogen (*Phytophthora cinnamomi)*, several factors contribute to the disease complex including: low soil fertility (primarily nitrogen), heavy clay soils or shallow soils underlain by a clay hardpan, poor soil drainage, and the presence of nematodes and *Pythium* species (pathogenic soil fungus). Historically, shortleaf pine growing on highly eroded clay soils found in the Piedmont area of southeastern states have had the highest vulnerability to this disease.

*Phytophthora cinnamomi* seldom affects trees less than 20 years old. The first observable symptoms of the disease are thinning crowns, needle necrosis, stunted needle growth, and reduced shoot growth. These are manifestations of the loss of fine roots and subsequent nutrient deficiency caused by the disease. Laboratory analysis is required for confirmation of *Phytophthora cinnamomi, Pythium* spp., and nematodes. Poorly drained soils favor the pathogen, which has spores that swim for short distances, increasing the rate of spread and risk of infection. Tree death occurs approximately six years after initial symptoms are observed.

Application of high nitrogen fertilizers can delay symptom development and mortality in high-value infected stands. Planting on high risk sites should be avoided unless contributing factors can be mitigated through improving soil fertility and increasing soil drainage. Soil characteristics, including texture and the presence of a hardpan, can be evaluated through soil surveys and onsite testing. To evaluate nutrient content, soil samples should be sent to a laboratory for testing. To increase availability of soil nutrients, fertilize stands according to recommendations from soil testing. In addition, interplanting legumes will improve nitrogen availability. To improve soil drainage, site preparation (e.g., breaking up hardpan layers) can be used. More intensive evaluation and site preparation should be considered when establishing shortleaf pine on former pastures and agricultural lands with clay soils where compaction and plow pans are common.

*Heterobasidion* root disease (also known as annosus or annosum root rot): ***Heterobasidion* root disease** is caused by the fungus *Heterobasidion irregulare* (formerly *H. annosum* or *Fomes annosus)* and infects trees via open wounds (primarily freshly cut stumps). It spreads to nearby trees through root grafts. Following infection, large roots near the base of the tree rot, leading to tree mortality or windthrow. All species of conifers are susceptible. Deep sandy and sandy loam soils with high pH and reduced organic matter are at highest risk while silt and clay loamy soils are at lower risk for the disease. Because freshly cut stumps are often the entry point of infection, recently thinned stands are most vulnerable. Planting on a wide spacing increases the time to first thinning, thus reducing the number of times the stand will need to be thinned. When thinning is necessary on a high hazard site, it should occur when the ambient temperature is above 85° F because spores germinate on stumps at cooler temperatures. If thinning must occur during cooler weather, it is recommended that stumps be treated with borax immediately after cutting. In severe cases, landowners should consider an early harvest to minimize volume losses.

Other Forest Tree Diseases: **Fusiform rust**, **needle blights**, and **needle casts** may also affect shortleaf pine. In addition, mature and overmature shortleaf pine trees may be subject to heartwood decaying **red heart disease**. In nurseries, **damping off** and **eastern gall** rust can cause damage/mortality and in seed orchards and nurseries conditioned with high levels of nitrogen, **pitch canker** also can be a problem. These diseases seldom cause sufficient damage to require direct control in forest settings.

## ABIOTIC FACTORS

Climate: Among all southern pines, shortleaf is the least exacting in terms of temperature and moisture requirements. This, combined with its tolerance of a broad range of soil and site conditions, helps explain why this species has the widest range of the southern pines. Throughout its range, annual **precipitation** varies from 40-60 inches per year. Snowfall amounts typically average less than 16 inches over most of its range, but in the Appalachians and into Pennsylvania, considerably more snowfall is tolerated. Shortleaf pine purportedly develops best where precipitation ranges from 45-55 inches and averages about 50 inches per year, including areas such as Arkansas, northern Louisiana, and the southern Piedmont. While shortleaf pine is found at **elevations** from 10 to 3,000 feet, it grows best between 600-1,500 feet in the Piedmont and 150 to 1,150 feet in east Texas, Louisiana and Arkansas.

Susceptibility to Fire and Extreme Weather: Shortleaf pine is considered better adapted to regular **fire** intervals than is loblolly pine. While it is relatively fire resistant, larger trees may be killed by intense burns, particularly if heavy fuel loads are present. In young plantations, fire can cause significant damage. However, unlike most other pine species, shortleaf pine will sprout from dormant buds until roughly ten years of age, forming new stems after main-stem damage.

Shortleaf pine is less susceptible to **windthrow** than loblolly pine on fertile sites where it is able to establish a taproot. However, it is more susceptible to windthrow on poor, shallow soils, where taproot formation is hindered. In general, shortleaf pine exhibits tolerance to **cold** and **ice storms** similar to that of loblolly pine. Where ice storms are relatively common, severe damage to shortleaf and loblolly pine plantations via main stem breakage often occurs, particularly in thinned, pole-size stands. However, due to shortleaf pine's ability to re-sprout, young shortleaf plantations are more likely than loblolly pine plantations to recover from ice or hail storms. As are many pine species, shortleaf is resistant to moderate drought, but extreme drought can cause severe stress and lead to *Ips* beetle attacks or direct mortality.

Soils and Topography: Shortleaf pine tolerates a wide range of **soil conditions**. While the best growth rates occur on the South Atlantic and Gulf Coastal Plains, most of the sites occupied by shortleaf pine are within the order Ultisols, suborder Udults. Ultisols are common in the humid climate of the southeastern U.S., are acidic and infertile, and usually support forestland or pastureland. Udults are moist and somewhat low in organic matter in the subsurface horizons. Such soils predominate across much of the Piedmont, and are commonly associated with littleleaf disease (discussed above). Within the suborder Udults, the most common great soil groups occupied by shortleaf pine are Paleudults and Hapludults. Paleudults have a thick clay horizon without much weathering, while Hapludults have a relatively thin clay subsurface horizon with significant weathering more likely.

Shortleaf pine **growth rates** are at a maximum ($SI_{50}$ > 100) on textures that are fine sandy loam or silty loam, which are typical of floodplain sites. The other extreme - very shallow, rocky soils on upland sites with lower rainfall - can have site indices as low as $SI_{50}$ = 33. In upland areas, site indices for natural stands are more typically between 50 and 75.

## SILVICULTURAL GUIDELINES

Site Selection: Prior to planting shortleaf pine, the landowner or forester should survey the soil profile to select an optimal site. As stated above, the most productive soils are deep, well-drained sandy loams and silty loams. Shortleaf pines are mostly found in soils that are usually moist and low in organic matter in the subsurface horizons. Growth tends to be poor in soils with a high pH, high calcium content, or excessive drainage. Due to its larger root system and deep taproot, lower tolerance for poorly aerated soil, and lower demand for nutrients, shortleaf pine tends to perform better than loblolly pine on drier, better drained, and less fertile Piedmont soils.

When selecting a site to grow shortleaf pine, sites with history or incidence of *Phytophthora cinnamomi* (the pathogen that causes littleleaf disease) should be avoided. Other site characteristics to avoid are considerable soil moisture deficits, poor aeration, low fertility, and/or nematodes. These conditions inhibit the absorption of mineral nutrients, particularly nitrogen.

Site Preparation: If the objective is to establish shortleaf pine through artificial regeneration on a new site, whether the site previously grew hardwoods or was an old field, site preparation is important. Exposing the soil prior to planting increases the success of initial establishment. Scarification during logging or burning is effective in both natural and artificial regeneration systems. Site preparation of former pastures and agriculture fields should include herbicides to control grasses/weeds and mechanical sub-soiling to break up plow-pans or compacted soil.

Management of competing species (e.g., hardwoods, other vegetation) is critical in a shortleaf pine stand. When young, shortleaf pine expends the majority of its energy on developing a root system; therefore, eliminating competition facilitates survival. Site preparation tools that reduce competition include herbicides, scalping, chopping, burning, and bedding. In addition, shortleaf pine is shade intolerant and does not grow well in an understory. It responds well to competition release at all ages up to maturity. Prescribed fire can be used to release shortleaf pine saplings but wildfires in young plantations can be damaging, especially if the crowns are killed. Hot fires also may kill larger shortleaf pine trees if the fuel load near the tree base is too heavy.

Regeneration: Shortleaf pine regenerates naturally from an existing seed bank. It is also an excellent species to regenerate through coppice management as seedlings and saplings sprout readily following injuries caused by fire, logging, or grazing.

## SEEDLING PRODUCTION

Seed Source: Provenance studies reveal that there is little variation among seed sources whether they arise from the Ozark – Ouachita highlands of Arkansas and Oklahoma or the Gulf Coastal Plain or Piedmont regions of the South. However, there is a high degree of variability within families from these regions. Recommendations are to acquire seedlings from a local seed source. If unavailable, use seed from the eastern upper coastal plain or Piedmont.

Seed Storage: Viability of seed can be maintained for up to 50 years with proper pre-storage treatment and storage conditions. The two primary components that impact seed viability are seed moisture and storage temperature. Following seed extraction and preprocessing to obtain clean seed with less than 1% aborted ovules, the seed should be dried to a moisture content of 8-10% and stored in bulk-sealed containers at a temperature of 0º F.

Seed Pretreatment: Seed dormancy is the largest factor affecting germination. Typical pretreatment of seed, whether freshly collected or retrieved from long-term storage, is to rehydrate the seed through immersion in 50º F water for 8 to 24 hours. After the seed are removed from the water bath, they should be placed in polyethylene bags or closed containers and stratified at 34º to 38º F for 30 days. An alternative to chilled stratification is to add an aeration component to the rehydration process. Seed can be soaked in continually aerated 50º F water for 72 hours, a method that allows complete bypassing of cold stratification.

Sowing: In just 10 years, seedling production shifted from more than 99% bare root (in 2003) to an equal split between bare-root and containerized. Bare-root production beds are prepared for seeding identically as for other pine species. Sowing is done using precision sowing equipment, placing a single seed in a drilled hole. Beds are then closed with a roller. Sowing should be done as early as possible in the year when seedbed temperatures are between 50° and 60° F (typically late March to mid-April). In container-production nurseries, sowing occurs by placing 1-3 seeds per container atop growing medium. It is then top dressed to keep the seed in contact with the medium and reduce floating out of the container during irrigation.

In both operations, moisture and light exposure affect germination. Photoperiods should mimic natural patterns where possible with at least 10 hours of light daily. In container-nursery production, photoperiod can be extended with artificial lighting for an additional 6 hours. Seedbed moisture should be regulated to ensure that soil/growing medium does not remain saturated for extended periods of time.

Thinning: In bare-root production, seedling thinning is typically not conducted. To ensure sufficient numbers of acceptable seedlings, plantings are done at a higher density or over a larger area. Quality assurance is achieved during the packaging process by eliminating inferior seedlings after seedlings are lifted. Container-production facilities thin seedlings when more than one seedling sprouts per cell. It is typically done 4 weeks after germination, favoring the best-performing germinant within the container.

Pruning: Bare-root nurseries usually root prune seedlings to loosen the bed prior to lifting and to promote lateral root development. If pruning is done to enhance lateral root production, irrigation should be applied immediately afterward to minimize the impact to growth from moisture stress. If root pruning is performed to facilitate lifting, it should be done no less than two weeks prior to lifting and packaging to allow for seedling recovery. Top pruning of shortleaf is not recommended.

## TREE IMPROVEMENT

Over the past 40 years, shortleaf pine tree improvement programs have developed to the point that all demand for planting stock is met with genetically improved trees. First-generation improvement efforts realized 10 to 15% gains and second-generation gains have doubled. Arkansas, Georgia, North Carolina, Oklahoma, South Carolina, Tennessee, and Virginia currently produce improved shortleaf pine seedlings. The largest owner of advanced shortleaf pine seed production orchards is the USDA Forest Service, which has orchards in Arkansas, Louisiana, Mississippi, and South Carolina. Geographic sources represented in these orchards include Missouri and all of Region 8 except for Alabama, Florida, and South Carolina. In total, there is in excess of 600 acres of seed orchard production capacity representing more than 500 family clones.

Progeny Testing: Controlled crosses within the original 12 sources began in 1974. After recognizing the interest for specific sources, the breeding plan was modified to include 5 geographic sources. 75% or 1,300 crosses have been implemented resulting in 123 established progeny tests including a minimum of 15 families each. In addition to the gains in volume growth, improvements were achieved in grain straightness and post-establishment survival. Grain straightness is highly heritable and has a significant impact on market value when trees are harvested. Following the increase in survival, survival rates for shortleaf pine plantations exceeds 90%, a 22% improvement over woods-run seedlings.

Selection for Resistance: The anecdotal evidence that shortleaf pine is resistant to damage from ice and snow loading is widely accepted, but little research has been conducted to document this trait. This represents a knowledge gap that should be addressed, especially with regard to the potential impacts of climate change. Similarly, its resistance or susceptibility to littleleaf disease has not been documented on a sufficient scale to incorporate into selection methodology for the next generation of progeny testing.

## CONCLUSION

To effectively communicate with landowners, the shortleaf pine advocate should have a general understanding of the forest health considerations specific to shortleaf pine restoration. Generally, shortleaf pine is comparable to other pines with respect to forest health issues, except on certain soils where littleleaf disease may be of concern. Before deciding to plant shortleaf pine (or any other species of pine), landowners should consider the soil and site characteristics and their forest management objectives. With proper silvicultural practices and routine monitoring for forest health issues, shortleaf pine can be successfully grown and managed on a variety of sites throughout its range. For more information, readers should refer to the silvics manual by Burns and Honkala (1990).

**REFERENCES**


Baker, W. L. 1972. Eastern Forest Insects. Misc. Publ. No.1175, USDA Forest Service, Washington, DC. 642 p.

Billings, R. F. 2011a. Aerial detection, ground evaluation, and monitoring of the southern pine beetle: State perspectives. Pp. 245-261, *In* R.N. Coulson and K. Klepzig, eds. Southern Pine Beetle II. 2011. USDA Forest Service, Southern Research Station Gen. Tech. Report SRS-140.

Billings, R. F. 2011b. Mechanical control of southern pine beetle infestations. Pp. 399-413, *In* R.N. Coulson and K. Klepzig, eds. Southern Pine Beetle II. USDA Forest Service, Southern Research Station Gen. Tech. Report SRS-140.

Burns, Russell M., and Barbara H. Honkala, tech. coords. 1990. Pp. 630-652, *In* Silvics of North America: 1. Conifers. Agriculture Handbook 654. USDA Forest Service, Washington, D. C. vol.2, 877 p.

Campbell, W. A., and Copeland, Jr., O. L. 1954. Littleleaf disease of shortleaf and loblolly pines. Agricultural Circular No. 940. U.S. Department of Agriculture. Washington, D. C. 41 p.

Lawson, E. R., and R. N. Kitchens. 1983. Shortleaf Pine. *In* R. M. Burns, ed. Silvicultural Systems for the Major Forest Types of the United States. USDA Forest Service. Agricultural Handbook No. 445. Washington, D. C.

Mistretta, P. A. 1984. Littleleaf disease. USDA Forest Service. Forest Insect and Disease Leaflet 20.

North Carolina Forest Service. 2012. Successful establishment of shortleaf pine (*Pinus echinata*). Forestry Leaflets FM-14.

Robbins, K. 1984. Annosus root rot in eastern conifers. USDA Forest Service. Forest Insect & Disease Leaflet 76.

USDA-FS. 1989. Insects and diseases of trees in the South. Protection Report R8-PR-16, June 1989. USDA Forest Service, Southern Region, Atlanta, Georgia. 98 pp.

**Table 1.** Relative risk of shortleaf pine to biotic and abiotic factors compared to other species of southern pines.

| Category | Causal agent | Shortleaf | Loblolly | Longleaf | Slash |
|---|---|---|---|---|---|
| Insects | Tip moths | high | high | low | moderate |
| | Leafcutting ants (TX and LA only) | moderate | high | low | low |
| | Regeneration weevils | high | high | moderate | moderate |
| | Engraver beetles (*Ips spp.)* | high | high | low | moderate |
| | Southern pine beetle | high | high | low | moderate |
| | Black turpentine beetle | low | moderate | high | moderate |
| | Pine sawflies | high | high | low | moderate |
| | Coneworms | moderate | high | high | high |
| | Seed bugs | high | high | high | high |
| | Aphids | low | moderate | low | low |
| | Scales | moderate | moderate | low | low |
| | Pine webworm | low | low | low | low |
| Diseases | Fusiform rust | low | moderate | low | high |
| | Littleleaf disease | high | moderate | low | low |
| | *Heterobasidion* root rot | moderate | high | low | low |
| | Pitch canker | low | high | low | high |
| | Needle diseases | moderate | high | low | low |
| | Damping off | moderate | moderate | low | low |
| | Cone rusts | low | low | moderate | moderate |
| | Brown spot needle blight | low | low | high | low |
| | Red heart disease | moderate | moderate | moderate | low |
| Abiotic factors | Wind | low | high | low | moderate |
| | Drought | moderate | high | moderate | moderate |
| | Hail/frost/ice | high | high | low | low |
| | Fire | moderate | high | low | moderate |
| Animals | Deer | moderate | moderate | low | low |
| | Rabbits | low | low | low | low |
| | Beaver | low | low | low | low |
| | Gophers | low | low | low | low |
| | Hogs | low | low | moderate | low |

**Table 2.** Major forest health concerns for shortleaf pine by developmental stage.

| Developmental stage | Major Factor | Occasional Factor |
| --- | --- | --- |
| **Seed orchard** | Coneworms<br>Seed bugs | Drought |
| **Nursery** | Damping off | Leafcutting ants (TX & LA only)<br>Fusiform rust |
| **Less than 5 years old** | Regeneration weevils<br>Leafcutting ants (TX & LA only)<br>Drought<br>Fire<br>Tip moths | Sawflies<br>Deer, rabbits |
| **Saplings (5-12 years old)** | Sawflies<br>Hail/ice | Pitch canker<br>Drought<br>*Ips* engraver beetles |
| **Pulpwood (13-20 years old)** | *Ips* engraver beetles<br>Southern pine beetle<br>Littleleaf disease | Sawflies<br>Hail/ice<br>*Heterobasidion* root rot |
| **Mature timber (>20 years old )** | Southern pine beetle<br>*Ips* engraver beetles<br>Littleleaf disease (primarily Piedmont)<br>Red heart disease | Sawflies<br>Hail/ice<br>Black turpentine beetle |