Longleaf Pine Regeneration[1]

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Longleaf pine (*Pinus palustris*) has many favorable characteristics for landowners who have long-term, multiple-use resource management objectives. Of all the southern pine species, longleaf pine is the most insect-, disease-, and fire-resistant and has the greatest longevity. When burned regularly, longleaf pine forests develop a stable grass savannah ecosystem, providing ideal habitat for many plants and animals.

Longleaf pine is a pioneer species on a variety of sites but is intolerant of competition and flooding during its grass stage, when it appears like a clump of grass. Historically, fire and moisture have been the principal factors controlling longleaf distribution within its natural range. In the lower Coastal Plain longleaf grows on sandy, well-drained to excessively well-drained soils where loblolly or slash pine perform more poorly. Fire removes competing vegetation, exposing the bare soil necessary for successful seedling establishment. In the historic fire-dominated longleaf pine grass savannah ecosystem, relatively stable plant communities are characterized by an overstory of uneven-aged, widely spaced longleaf pines and fire-tolerant oaks such as bluejack oak (*Quercus incana*) and turkey oak (*Quercus laevis*) and a predominate ground cover of bunch grasses such as wiregrass (*Aristida beyrichiana*) and bluestems (*Andropogon* spp.) which facilitate ignition and spread of periodic fires (Landers 1991). It is interesting to note that, despite this tree's performance on high, dry ground, its Latin name means "swamp pine." It does grow sparsely in wet areas as well.

Artificial Regeneration

Options for artificial regeneration include planting bareroot or containerized seedlings or direct seeding. Control of pine stocking (density) is best when seedlings are planted and container-grown seedlings generally provide the best survival rate. However, direct seeding may be a viable

1. This document is SS-FOR-13, one of a series of the School of Forest Resources and Conservation Department, UF/IFAS Extension. Original publication date January 2000. Revised November 2010, January 2017, and July 2020. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of the publication.

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option for some situations, such as regenerating relatively small areas.

Site Preparation

Longleaf pine is very intolerant of shade and is difficult to regenerate successfully without vegetation control. Vegetative competition around seedlings must be kept at a minimum until an adequate number of seedlings emerging from the grass stage are at least as tall as the competition. The choice of site preparation methods before planting longleaf seedlings or direct seeding will depend on the regeneration technique used, site conditions and your management goals.

At the very least, prepare areas for direct seeding by first performing a prescribed burn. Disking also enhances seeding establishment by exposing mineral soil and reduces competing vegetation for a short period of time. Most site conditions require more extensive site preparation techniques to increase the likelihood of success.

The most common situations encountered are recently harvested forest sites and conversion of old fields and pastureland. On recently harvested forest sites control of hardwoods prior to planting is critical and is accomplished by the use of machinery, fire, and herbicides, most often in some combination. Residual standing hardwoods should be removed with heavy machinery such as a root rake or controlled using individual stem herbicide treatment such as imazapyr or triclopyr amine "hack and squirt" (Table 1). However, the greatest challenge to longleaf reforestation is controlling the hardwood "root mat", an extensive and long-established interconnected root system from which dense stands of hardwood stems quickly overtop planted longleaf while they remain in the grass stage. Intensive mechanical site preparation such as root-raking, piling, and burning piles provides hardwood control; whereas, low-intensive mechanical site preparation such as chopping and burning generally increases hardwood competition because the disturbance promotes sprouting (Lowery and Gjerstad, 1991). Generally, the use of broadcast site preparation herbicide treatment provides better hardwood control and at a lower cost than the use of machinery (Lowery and Gjerstad, 1992, Dickens et al. 2008, Dickens et al. 2018). Following herbicide treatment, broadcast site preparation burning is often done to improve hand or machine planting access. V-blade planters are used to improve machine planting access by pushing debris away from the planted row. Common broadcast herbicide treatments for control of hardwoods prior to planting longleaf are summarized in Table 1.

On old fields and pastures ripping will help break hardpans (compacted soil layers) and scalping a narrow (1–2 ft) strip, about 2 to 3 inches deep, along the planted row will break up the sod and improve the effectiveness of the planting machine in setting the seedlings with good soil contact. Scalping and ripping are usually done following the contour on sloping land to avoid erosion problems. It is best to rip the soil during dry periods in the summer to obtain good soil fracture and well in advance of the planting season, so that eventually rain will settle the soil prior to planting in the late fall or winter. When planting into established grass sod, the most effective practice is to deaden the sod with glyphosate herbicide (Table 1) either by broadcast application or by treating a 5–6 ft wide band centered on the planted row *prior to planting*. Herbicide control of grasses is very important for successful longleaf establishment, and glyphosate is most effective when applied during periods of active grass growth. Disking established sod prior to planting is not recommended because it makes herbaceous vegetation control after planting very difficult.

The best results are obtained when vegetation is managed both before and after planting. During the first and sometimes the second growing season following planting, selective herbicides are used to control grasses and broadleaf weeds (herbaceous weed control). This practice significantly improves seedling survival and accelerates seedling growth rates by reducing the period that seedlings remain in the grass stage by one or more years. For longleaf plantations in the sandy soils of the Coastal Plain, hexazinone and sulfometuron methyl are the most commonly used herbicides for herbaceous weed control (Table 1). These herbicides may be applied directly over planted seedlings safely when care is taken to ensure the proper herbicide rate is applied and labeled method is followed. These herbicides provide pre-emergence weed control (preventing weed development) or early post-emergent control (effective on very small newly emerged weeds) and are generally applied during the last week of March though the first two weeks of April. Sulfometuron is not effective on established weeds, but hexazinone is effective on established weeds (post-emergence). Pine tolerance to these herbicides is best when seedlings have initiated new root growth following transplanting. Many growers excavate a few trees prior to herbicide application to check for new roots, which are white in color.

Recent "State Special Local Need Registrations" (SLNR) in AL, FL, GA, LA, MS, NC, TX, and VA for aminopyralid herbicide (Milestone®) have improved options for post-emergence applications in newly planted and young

longleaf plantations (Table 1). This selective herbicide may be applied over-the-top of longleaf seedlings to control of broadleaves, blackberry, other vines, and provides some hardwood brush suppression. Effectiveness is best in spring or early summer, but it may be applied later in the growing season. A single annual application may be made starting 2 months after planting, with treatments typically made during the first or second growing seasons when seedlings are in the grass stage. Note that this herbicide may damage pines during growth flush of the apical leader as longleaf trees emerge from grass stage and this timing should be avoided. The SLNR labels for LA, MS, TX, and VA have a specific recommendation for a tank mix with imazapyr (Arsenal® AC) which will improve hardwood brush control.

Once seedlings are established, a prescribed burning program is a natural and cost-effective means to manage hardwood vegetation and also shift the ground cover to grass savannah species which provide desirable habitat for many desired wildlife species (Platt et al. 1998; Noss 1989).

Planting

Since longleaf pine seedlings do not become truly dormant, they require greater care in handling and planting than other southern pines. The success of longleaf pine planting depends on (1) good soil moisture at and following planting; (2) a well-prepared, competition-free site; (3) fresh, healthy, top quality planting stock; (4) extreme care in handling the stock from lifting to planting; (5) quality planting; and (6) managing competing vegetation through stand establishment. High quality seedlings can be grown as either bareroot or container stock, but container stock is somewhat more forgiving of less than optimum conditions.

The appropriate planting density will depend on your objectives. Low planting densities, 300 to 500 seedlings per acre or less, may be appropriate for longleaf ecosystem restoration and/or to provide wildlife habitat (such as that for bobwhite quail), whereas as many as 750 seedlings per acre or more may be desirable to optimize timber production and pine straw raking.

Supplies of longleaf pine seedlings may not be sufficient to meet demands, so order your seedlings by early summer at the latest. For a list of longleaf nurseries, call your Florida Forest Service County Forester (https://www.fdacs.gov/Divisions-Offices/Florida-Forest-Service/For-Landowners/County-Foresters) or the Longleaf Alliance, at 334-427-1029, and request a copy of the *Longleaf Nursery List*. This is also available on their website: https://longleafalliance.org/.

Choose a tree planting contractor that has experience with planting longleaf pine. Planting failures frequently result from improper seedling handling and planting. Hiring an experienced and reputable contractor may help to ensure seedling survival and minimize the possibility of having to replant.

BAREROOT SEEDLINGS

Longleaf pine seedlings at the nursery are stem-less and resemble a carrot with a clump of pine needles on top. Ideally, bareroot seedlings should have (1) a root collar diameter (RCD) of 0.4 to 0.6 inch; (2) a stout, 6- to 8-inch or longer tap root; (3) at least 6 well-developed, 6- to 8-inch lateral roots with evidence of ectomycorrhizal development; (4) a winter bud with scales; (5) abundant, large, fascicled needles that are free of brown-spot disease; (6) been grown at a reputable nursery; (7) been undercut in the nursery bed well before lifting; and (8) a seed source from the same region as the planting site. Seedlings with a RCD of 0.3 inch or less generally have low survival rates.

Longleaf seedlings come out of the grass stage and initiate stem height growth when the seedlings have a RCD of about one inch. After planting, longleaf seedlings allocate their growth to develop a tap root prior to initiating stem height growth. As noted above, seedlings may initiate height growth at a younger age if competing vegetation is controlled. Once the seedlings emerge from the grass stage, height growth is comparable with loblolly or slash pine of the same age.

CONTAINERIZED SEEDLINGS

There is increasing interest in using containerized longleaf pine seedlings (plugs) because they generally have greater survival than bareroot seedlings. Also, containerized seedlings can be planted throughout the year, whenever soil moisture is adequate *before and after planting.* Containerized seedlings have even been successfully planted during the hot summer months, when afternoon rains are common. They can be used to replant partial regeneration failures in the year they occur as well. Studies have shown that both fall-planted and late winter-planted containerized longleaf seedlings *often* have better survival and growth than winter-planted bareroot seedlings. Seedlings grown in large containers (large plugs) can enhance survival on adverse sites, but to ensure success sufficient site preparation and vegetation control measures must be taken.

The main drawback of containerized seedlings is cost. On average, the price per thousand is about twice as much for container-grown seedlings as the cost for bareroot

seedlings. The larger the plug volume, the greater the cost to produce the plugs. Also, containerized seedlings are bulkier to handle during shipping and planting. However, cost-share programs and increased survival make them a feasible option.

NURSERY TO FIELD

Proper care and handling of seedlings from the nursery to the field includes several steps: (1) pick up seedlings from the nursery the day they are lifted; (2) protect roots from desiccation; (3) protect seedlings from wind and refrigerate them if possible during transportation to the planting site (place plugs loosely in large coolers or waxed boxes); (4) store seedlings in a cool, well-ventilated area for no more than three days before planting (or up to 3 weeks in refrigeration, 5 weeks with humidity control); and (5) do not expose seedlings to sunlight or heat. To optimize success, plant seedlings within three days of pickup from the nursery. Large planting jobs may require multiple trips to the nursery.

Longleaf seedlings are normally planted between November and the beginning of March when cool temperatures are prevalent, and soils are normally moist. Planting during the early part of this time frame is best to give seedlings time to grow new roots before the dry weather of April and May. Containerized seedlings can be planted earlier whenever available soil moisture is adequate and rainfall occurs as noted above, but risks are diminished during the winter planting season. Avoid planting during periods of low soil moisture, dry weather, high temperature, low relative humidity, high winds or when soil is frozen.

Take enough seedlings to the field for one day of planting and keep them moist, but not submerged. When hand-planting bareroot seedlings, keep a little water or wet Tera-Sorb in the bottom of the planting bag. Make sure tree planters carry seedlings in the bag to prevent the roots from drying out.

For **bareroot seedlings**, machine planting is preferable to hand planting because the larger slit created by the machine provides for better root alignment. If hand-planting, bareroot seedlings should be planted with a shovel or large dibble. Containerized seedlings can be planted with a cylinder-type dibble or any of the flat-bladed implements used to plant bareroot stock.

For bareroot stock, position seedlings with taproots straight down and root collars at or slightly below the ground line (no more than 1 inch below), which allows the bud to be exposed once the soil has fully settled. Attention to detail during planting is critical—a seedling planted too shallow will die quickly, and a seedling planted too deep will die slowly.

For **containerized seedlings**, position the plug so that the terminal bud is just slightly above the soil surface to insure the seedling is not planted too deep; the terminal bud must remain above the soil surface. Planting plugs too shallow could cause them to dry out and die.

Do not plant directly in a subsoiled/ripped furrow because the seedlings may sink. Instead, offset 2–4 inches to the side of the ripped furrow.

On scalped sites with sandy soil, soil movement back into the scalped furrow should be anticipated, and containerized seedlings should be planted somewhat more shallowly. Optimum planting depth will depend on conditions; sandy soils and sloping ground tend to have more soil movement. Recent research by the Longleaf Alliance suggests that on scalped sites prone to soil movement leaving approximately ½ to 1 inch of the plug above the soil surface may position the terminal bud at an optimum final height, favoring good survival. However, keep in mind that planting plugs too shallowly will increase the risk of the seedlings drying out and dying, especially if an extensive dry period follows planting.

A WORD ABOUT COST-SHARE CONTRACTS

If you have a cost-share contract under the USDA's Conservation Reserve Program or Environmental Quality Incentives Program, the planting crew must know about it. If not, they may plant more than the maximum number of seedlings allowed in the terms of the contract, causing problems with your funding.

POST-PLANTING CARE

Once seedlings are planted, the principal factors affecting seedling development are vegetative competition and brown-spot needle blight. Prescribed fire is the most common cultural treatment used to control both. If average brown-spot infection exceeds 20% of the cumulative foliage on sampled seedlings, a burn will be needed to control the disease unless it will result in excessive mortality. Seedlings in the early stages of height growth (coming out of the grass stage) are most susceptible to fire kill, especially when heavily infected by brown-spot.

Direct Seeding

Due to increases in seed costs, this once cost-effective regeneration option is now potentially cost prohibitive, and

it involves substantial risk. Failure can occur as a result of inadequate control of competing vegetation, low seeding rates, using seed not treated with bird or rodent repellent, seeding at the wrong time, or adverse weather conditions. Often, direct seeding results in stands with patchy stocking, with some areas not adequately stocked and some areas with too many trees. Low, poorly drained sites that are likely to be covered with standing water a week or more after seeding should be avoided. Likewise, deep upland sands that dry out rapidly after a rain are also unsuitable for direct seeding. Generally, sites that can be successfully planted can also be successfully seeded. As with planting, site preparation methods must control vegetative competition and expose at least 50% of the mineral soil. Seeds must be in contact with the mineral soil for germination to take place. Seeds lodged in non-soil material will probably not become established.

In general, local seed sources are best. Seed or seedlings from North and South Carolina tend to grow poorly when planted on the Florida peninsula and vice versa. Most genetic improvement work with longleaf pine is concentrated on breeding for brown-spot disease resistance and accelerated initial height growth.

Purchase seeds from a reputable seed dealer. Longleaf seeds should be refrigerated at subfreezing temperatures until sowing. Sowing can take place in fall, when moisture is adequate and maximum daytime temperatures drop below 85 degrees. Seed can be sown at low cost by broadcast seeding at 3 pounds per acre, or spot seeding (dropping 3 to 5 seeds per spot). Row seeding, at 1 to 2 feet spacing between seeds, can be used when better control over spacing and density is desired. Large areas are best seeded by aircraft which use carefully calibrated equipment. After establishment (two to three years), clumps of seedlings can be thinned down to one tree.

Natural Regeneration for Even-Aged Stands

Landowners who already have stands of longleaf pine can take advantage of a practical, inexpensive natural regeneration method known as the *shelterwood* system, a natural seeding method well-suited to the biological requirements of this species. The shelterwood method maximizes per-acre seed production and yields sufficient needle litter to fuel fires hot enough to inhibit hardwood regeneration and to prepare a seed bed. Regular prescribed burns should be scheduled throughout the rotation to maintain a low understory. The mature stand is removed in a series of three harvests, with a portion left standing as a seed source until regeneration is well established. Success with this method depends on (1) a good seed year with adequate seed supply, (2) a receptive seedbed, (3) minimal vegetative competition and (4) ample soil moisture.

The three harvests of the shelterwood system serve 3 basic purposes: (1) to prepare the stand for production of abundant seed, (2) to modify the environment in a way that promotes germination and survival, and (3) to build up the amount and size of advance regeneration to ensure a well-distributed stand following overstory removal.

Preparatory Cut

The preparatory cut may be 10 or more years before the planned final "removal" harvest date of the stand and at least 5 years before the "seed cut". This preparatory cut is essentially a thinning which reduces the basal area (BA) of the stand to a maximum of 60–70 square feet per acre of dominant and codominant pines. This cut promotes crown development and cone production. Most of the hardwoods not controlled by fire should also be cut at this time.

Seed Cut

The seed cut is made 5 years prior to the planned removal harvest and leaves no more than 30 square feet BA per acre of the largest dominant trees, with well-developed crowns and best stem form, typically 15 inches diameter at breast height (dbh) or greater. Trees with evidence of past cone production are favored. Cone production peaks in the range of 30 to 40 square feet BA per acre, but the lower end of this range is preferred because logging-related seedling losses increase when more trees are removed in the final cut.

Monitor the cone crop by taking spring binocular counts of both flowers (next year's cone crop) and 1-year-old conelets (this year's cone crop) on selected sample trees in the regeneration area. These counts will give an estimate of the potential for the cone crop to regenerate the stand so that the seedbed can be prepared before the cones open. Generally, few seeds are produced by trees under 30 years old or under 10 inches dbh.

In order to achieve adequate natural regeneration, the available seed supply must feed various forms of wildlife with enough left over to establish a satisfactory stand. A minimum of 750 to 1,000 or more cones per acre is needed for successful regeneration. Longleaf cone crops are highly variable. Good seed crops occur every 5 to 10 years. Seedfall begins in late October and continues through

November, but most seeds fall within a period of 2 to 3 weeks. About 70% of viable seeds fall within 65 feet of the parent tree. Under favorable weather conditions, seeds will germinate one or two weeks after dispersion. A prescribed burn 1 year before seedfall will remove accumulated litter and expose sufficient mineral soil for seedling establishment. A late-spring burn is most effective in controlling woody stems.

Removal Cut

Once an acceptable stand of seedlings is established, the parent overstory can be removed. This cut can be delayed if necessary for management needs or market conditions. Seedlings can survive 8 or more years under the parent overstory with little or no effect on survival given exclusion of burning. However, logging damage becomes more serious once seedling height growth begins and fire exclusion leads to encroachment of competing hardwoods.

Naturally regenerated stands require the same attention as planted stands with respect to brown-spot disease and competing vegetation. Young stands should not be burned until at least 2 years after the removal cut to allow time for logging slash to decay and the seedlings to respond to release.

Natural Regeneration for Uneven-Aged Stands

Uneven-aged stands are created using the selection system. In the selection system, trees representing a range in diameter classes are harvested at fixed intervals (called the cutting cycle, which ranges from 10 to 25 years). Regeneration (either natural or artificial) occurs in the harvested openings. This management approach allows periodic harvests, while maintaining a continuous forest cover. Smaller, lower quality trees are also removed to improve the overall quality of the stand. This method is covered in detail in this publication on opportunities for uneven-age management: https://edis.ifas.ufl.edu/fr132.

Conclusion

Longleaf pine has many desirable characteristics for landowners who have multiple-use forest management objectives. On appropriate sites, and with careful attention to detail during the regeneration phase, it is possible to enjoy the versatility of this species without compromising growth rates.

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Table 1. Common herbicide treatments for longleaf pine establishment. Read and follow all label directions.

Herbicide Common Name	Herbicide Rate	Trade Name	Amount Product per Acre	Comments
Individual stem treatment (IST) to control competing hardwood trees prior to planting				
Imazapyr	Mix 6 fl. oz product per gal water. Apply 1 ml per cut with no more than 1 inch between cuts.	**Arsenal® AC, Polaris® AC Complete**	**Do not exceed 40 fl. oz/Ac**	A persistent soil-active herbicide. See product label directions for cut surface (hack and squirt) application with diluted solutions.
Triclopyr amine	Mix 50% product in water and apply 1 ml to overlapping cuts around entire stem.	**Garlon® 3A**	**Do not exceed 2.67 gal./Ac**	Negligible root uptake from soil. See product label for hack and squirt application with diluted solutions.
Site preparation of recently harvested forest sites primarily to control hardwood and shrub vegetation prior to planting:				
Hexazinone	For soil types:	**Velpar® L VU**	For soil types:	Hand "spotgun application" to soil on grid pattern or to soil around individual rootstocks in spring (see product label). Works well for oak control on sandy soils with good longleaf pine tolerance.
	Sand, loamy sand, sandy loam 2-3 lb ai/Ac		4-6 qts/Ac	
	Loam, silt loam, sandy clay loam 3-4 lb ai/Ac		6-8 qts/Ac	
	Silty clay loam, clay loam, sandy clay, silt, silty clay, clay 4-5 lb ai/Ac		8-10 qts/Ac	
Imazapyr plus **Glyphosate**	0.625 lb ai + 3.0 lb ai/Ac	**Chopper®** **Accord® XRT**	40 fl. oz + 2.2 qts/Ac	Broadcast by helicopter or ground sprayer. Very broad-spectrum hardwood control. Add 1% (v:v) methylated seed oil (MSO) surfactant to improve control.
Site preparation prior to planting on fallow pasture sites:				
Glyphosate	2.0 lb ai/Ac	**Accord® XRT**	1.5 qts/Ac	Foliar application with no root uptake. Broadcast or apply as a six-foot-wide band in the late growing season prior to planting. Add 1% MSO surfactant.
Pre-emergence herbaceous weed control (grasses and broadleaf weeds) applied over-the-top of planted longleaf seedlings in early spring, at least one month after planting to allow for new root growth prior to herbicide treatment.				
Hexazinone plus **Sulfometuron**	6 oz ai/Ac + 1.5 oz ai/Ac	**Velpar® L VU** **Oust® XP**	24 fl. oz + 2 oz mass/Ac	Tank mix, very broad spectrum for grasses and broadleaves.
Hexazinone plus **Sulfometuron**	6.3-12 oz ai/Ac 1.2-2.2 oz ai/Ac	**Oustar®**	*10-19 oz mass/Ac	Pre-packaged mix, very broad spectrum. Use lowest rate on sands, highest rate for clay soils. See product label for soil texture herbicide rate guidelines.
Post-emergence control of broadleaves, blackberry, other vines, and provides some hardwood brush suppression with a single application. Aminopyralid may be applied over-the-top of longleaf seedlings 2 months after planting with best effectiveness in spring or early summer. State "Special Local Need Registration" in AL, FL, GA, LA, MS, NC, TX, and VA. Must have copy of the State Supplemental Label during application, please see links to labels below.				
Aminopyralid	Up to 0.11 lb ae/Ac	**Milestone®**	Up to 7 fl. oz/Ac	Apply as a broadcast or band over-the-top of longleaf or as a directed spray, typically applied in first or second year after planting when pines are in the grass stage. * No added surfactant * May damage pines during growth flush of apical leader as they emerge from grass stage.