



# Restoring the Longleaf Pine Ecosystem: The Role of Container Seedling Technology

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**Abstract**—Longleaf pine (*Pinus palustris* Mill.) ecosystems once occupied 90 million acres in the southern United States' coastal plain. Restoration of longleaf pine ecosystems has been difficult because reestablishment of the species by either natural or artificial means has been problematic. The application of container seedling technology to longleaf pine markedly improves reforestation success. It allows nursery managers and silviculturists to more effectively deal with the inherent seed and seedling characteristics that make longleaf establishment so difficult. Improved seed collecting and processing and seedling cultural techniques have resulted in planting stock that can be successfully established in the field. As a result, a 10-fold increase in longleaf pine seedling production has occurred in the last few years to meet restoration needs across the South.

## Introduction

Restoration of the longleaf pine (*Pinus palustris* Mill.) ecosystem in the southern United States is receiving a great deal of attention (Landers and others 1995, Noss 1989). Longleaf pine ecosystems once occupied over 90 million acres from southern Virginia to central Florida and west to eastern Texas (Frost 1993). These fire-dependent ecosystems dominated a wide array of sites within the region. Today, less than 4 million acres remain (Kelly and Bechtold 1990), with much of this in an unhealthy state. This extensive ecosystem that once contained tremendous timber resources, wide ecological diversity, and essential habitat for many unique plant and animal communities has nearly vanished. Restoration of the ecosystem is an objective on most southern coastal plain National Forests. It, too, is a desired condition on other federal and state lands, as well as on lands of many private landowners. However, until recently, regeneration of the longleaf pine ecosystem has been problematic due to lack of an adequate seed supply, reduction in use of fire that controls competition, poor establishment success with bareroot seedling stock, and seedlings that require several years to initiate height growth.

The success in restoration of the ecosystem is largely the result of recent improvements in the technology to artificially regenerate longleaf pine. This improved technology is based on a better understanding of the ecology of this species. The objectives of this paper are to describe the nature of the longleaf pine ecosystem and its ecological and economic values, and to review the development of the container seedling technology that facilitates the restoration of the species.

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# The Longleaf Pine Ecosystem

The natural range of longleaf pine covers most of the Atlantic and Gulf Coastal Plains with extensions into the Piedmont and mountains of north Alabama and northwest Georgia. The species occurs on a wide variety of sites, from wet, poorly drained flatwoods near the coast to dry, rocky mountain ridges (Boyer 1990). It is a long-lived tree, potentially reaching an age of several hundred years; but longleaf pine forests are often exposed to catastrophic hazards such as tropical storms and to continuing attrition from lightning strikes that cause tree mortality and shorten possible rotation ages (Landers and others 1995).

Longleaf pine is a very intolerant pioneer species and the seedlings go through a stemless grass stage that is usually broken when the young stand and grass is burned in a low intensity ground fire. If competition is severe, they may remain in this grass stage for years. The ecosystem is distinguished by open, park-like stands with a grassy understory, which are composed of even-aged and multi-aged mosaics of forests, woodlands, and savannas, with a diverse groundcover dominated by bunch grasses and usually free of understory hardwoods and brush (Landers and others 1995). The diversity of understory plants per unit of area places longleaf pine ecosystems among the most species-rich plant communities outside the tropics (Peet and Allard 1993). Although the forests are known for persistence and diversity, they often occur on infertile soils. The ecological persistence of these areas is a product of long-term interactions among climate, fire, and traits of the key plants.

Fire was an essential component of the original longleaf pine ecosystems. Longleaf pine and bunch grasses (e.g., wiregrass and certain bluestems) possess traits that facilitate the ignition and spread of fire during the humid growing seasons (Landers 1991). Frequent fire was largely responsible for the competitive success of longleaf pine and its associated grasses. These keystone species exhibit pronounced fire tolerance, longevity, and nutrient-water retention that reinforce their dominance and restrict the scale of vegetation change following disturbance. Fires that were ignited by Native Americans or that resulted from thunderstorms with frequent lightning prevailed over the region. Many of these fires occurred during the growing season and largely prevented species native to other habitats from encroaching into the pine barrens. The chronic fire regime also maintained the soil structure and poor nutrient dynamics to which longleaf pine is adapted (McKee 1982). These fire effects tended to make longleaf pine sites more favorable to resident species than those indigenous to more nutrient-rich habitats.

## Decline of the Longleaf Pine Ecosystem

The depletion of the longleaf ecosystem resulted from its many desirable attributes that have caused it to be exploited since the settlement of the nation by Europeans (Croker 1979). However, it was the event of railroad harvesting in the late 1800s and early 1900s that provided access to and depleted the vast remaining longleaf timberland. Cutting proceeded from the Atlantic states west through the Gulf Coast Region with increasing intensity of use with time. Longleaf pine logging reached a peak in 1907,

when an estimated 13 billion board feet were cut (Wahlenberg 1946). The longleaf pine ecosystem now occupies only a small part (less than 5 percent) of its original area. This habitat reduction is the reason for the precarious state of at least 191 taxa of vascular plants (Hardin and White 1989, Walker 1993) and key wildlife species such as the red-cockaded woodpecker, gopher tortoise, and southern fox squirrel (Landers and others 1995).

Regeneration of longleaf pine was limited because of a combination of circumstances. The completeness of the harvest left little seed source for natural regeneration and much of the harvested land was cleared for cropland or pasture. Longleaf pine does not successfully invade open land in competition with more aggressive pine or grass species. Regeneration sometimes succeeded the removed old-growth when periodic fires provided a seedbed and controlled woody competition, and when wild hogs did not reach a density high enough to destroy established seedlings (Wahlenberg 1946). The disruption of natural fire regimes, resulting in part from forest fire protection policies implemented during the 1920s, allowed invasion of longleaf sites by hardwoods and more aggressive pine species. Regeneration, both naturally and artificially, is more difficult than for any other southern pine due to the delay in stem elongation (the grass stage) that is a genetic trait of the species. Also, survival of planted bareroot nursery stock is generally poor and established seedlings in the grass stage are very sensitive to competition.

## **Restoring the Ecosystem**

A key to restoration of the longleaf pine ecosystem is to ensure that society understands the value of the species and its habitat. Without economic benefits, long-term conservation projects usually do not succeed (Oliver 1992). Longleaf pine forests have high economic value due to the quality of solid-wood products produced. Harvesting or forest management need not be eliminated or restricted to restore and maintain longleaf pine ecosystems, as evidenced by the fact that logging at the turn of the century apparently had little effect on groundcover diversity (Noss 1989). Restrictions on harvest would be a disincentive to many landowners and could result in the elimination of much of the remaining longleaf pine on private lands.

Restoration of the longleaf pine ecosystem is achievable since pockets of longleaf pine occur across much of its former range. It should be feasible to gradually expand longleaf pine acreage through education, research, and commitment on the part of resource managers. Restoration is now a goal on much of the public land in the southern United States, where longleaf pine remains as a component of the forest. In fact, much of the current acreage of the ecosystem occurs on public lands.

A number of interacting factors will determine whether the restoration of the longleaf pine ecosystem can be achieved. These include the capability to successfully regenerate longleaf pine on its native sites, to use fire to enhance establishment and management of both the overstory and understory species, to educate the public and resource managers on the value and technology of restoration, and to evaluate restoration success.

### ***Restoration Technology***

Utilization of the trees in the original forest was so complete that inadequate numbers of seed trees remained to naturally regenerate many

of the harvested stands. So, artificial regeneration must be used to restore longleaf on many of the appropriate sites where it originally grew. Until recently, regeneration success from planting was generally unacceptable due to problems related to severe competing vegetation, delayed stem elongation, and poor storability of bareroot seedlings. We now have the knowledge and technology to reestablish longleaf pine by planting bareroot stock. The keys to successful establishment are: well-prepared, competition-free sites; healthy, top-quality, fresh planting stock; meticulous care of stock from lifting to planting; precision planting; and proper post-planting care (Barnett 1992). Failure to implement a single step in the regeneration chain of events can doom a plantation. Bareroot stock is very sensitive to damage during lifting, handling and planting, increasing the chance of poor performance when planted in the field.

### **Merits of Container Technology**

Planting of container stock is now accepted as the most successful method of regenerating longleaf pine (Barnett and McGilvray 1997). Production of longleaf container seedlings has increased from about 15 million to 85 million annually in the last five years. This improved survival and growth is generally attributed to root systems that remain intact during lifting while roots of bareroot plants are severely damaged. Thus, container seedlings experience a significantly shorter period of transplant shock or adjustment than bareroot stock. However, using container stock does not eliminate the critical need for controlling competition during the first growing season after planting.

The establishment of a facility to produce container seedlings is simple, and can be done at a fraction of the cost of establishing a bareroot nursery. A container nursery facility does not require any special attention to soil type or soil health, since seedlings are grown in potting medium in containers rather than in the soil where the nursery is located. Two elements of physical infrastructure are needed for the container nursery—an adequate supply of water for timely irrigation of seedlings, and some means to deploy netting over the seedlings as germination occurs to minimize predation of seeds from birds (Barnett and McGilvray 1997, Barnett and others 2002).

### **Essentials for Container Production**

Availability of high quality seeds currently limits production of longleaf pine container seedlings. Recently guidelines for producing quality longleaf pine seeds have been published that improve both germination and yield of plantable stock (Barnett and McGilvray 2002a). An important aspect of this increased performance is the reduction of seed coat pathogens that negatively affect germination and seedling establishment (Barnett and McGilvray 2002b).

Prompt and uniform germination is important in seedling production. Once germination has occurred, it is critical to follow established protocols for growing the seedling crop (Barnett and McGilvray 1997). Normally crops are sown in April and are ready to be outplanted in October or November—whenever soil moisture will allow.

### **Determining Stock Quality**

Until recently, broadly recognized standard specifications for container longleaf seedlings were lacking. Establishing standards based on research has been difficult because “substandard” container stock will survive in

**Figure 1**—Interim specifications for longleaf pine container seedling

Characteristics	Preferred	Not Acceptable
<b>Needles</b>		
Length if not top clipped	8 to 12 inches	<4 inches
Length if top clipped	6 to 10 inches	<4 inches
Fascicles	Many present	None present
Color	Medium to dark green	Yellow or brown
<b>Roots</b>		
Root collar diameter <sup>a</sup>	≥¼ inch	<3/16 inch
Color	Light brown with white tips	Black (diseased)
Mycorrhizae	Present (the more the better)	
Evidence of disease	None present	Any present
Root spiraling	None present	Any noticeable amount
<b>Buds</b>		
Present	Present on 90 percent of crop	
Color	Green to brown	Yellow or chlorotic
<b>Container size (per plant)</b>		
Diameter	≥1.5 inches	<1 inch
Length	≥4.5 inches	<3.5 inches
Volume	≥6 cubic inches	<5.5 cubic inches
<b>Other important attributes</b>		
Firmness: Plug stays intact when extracted and during handling; no loss of potting medium.		
Moisture: Root plug is always moist, never dry.		
Pests: No competing weeds or insects are present.		
Sonderegger: Buyer specifies whether to cull Sonderegger seedlings.		

<sup>a</sup> At base of needles

years when rainfall is abundant, but early development will be behind that of a good seedling. Developing seedling grades requires outplanting and performance evaluation of seedlings with a range of physiological and morphological characteristics—tested over a number of years and over a range of site conditions. Lacking the resources to conduct the research to establish standards, the Longleaf Alliance and two USDA Forest Service units—the Cooperative Forestry group in Atlanta and the Southern Research Station silviculture unit in Pineville—decided to seek agreement among producers and users on acceptable seedling criteria.

A canvassing of those who produce and use longleaf pine container stock for their recommendations revealed that available information was insufficient to develop three different seedling grades similar to those for bareroot stock (Wakeley 1954). So, we decided to develop only two, “preferred” and “non acceptable.” These guidelines (figure 1) are now used across the South (Barnett and others 2002).

### Application of Container Technology

Because of difficulty in obtaining consistent field survival with bareroot stock, about 85 percent of longleaf pines now planted are container grown seedlings. The ability to plant container stock early in the fall also improves field survival and early height growth on many sites. The ability of fall planted seedlings to establish a root system during the winter months usually results in earlier initiation of height growth.

### The Role of Fire

Fire is an essential component of the restoration and management of the longleaf pine ecosystem. Long-term studies show that the frequent use of

fire hastens initiation of height growth by reducing undesirable competing vegetation and foliage that is infected with brown-spot needle blight (*Mycosphaerella dearnessii* Barr.) (Siggers 1934). Longleaf pine seedlings that are in grass stage are resistant to injury by fire because the buds are protected by a rosette of needles (Walker and Wiatt 1966). Prescribed fire also stimulates growth and development of species that are an essential component of the understory. Seasonal burning studies show that late spring burns are much more effective in the restoration process than the typical winter burns that are usually favored by other pine species because they are hotter and more effective in reducing competing woody vegetation (Grelen 1978, Haywood and others 2001). Fire is an important element in establishing the species and is a critical component for achieving and maintaining the biologically diverse understory that is characteristic of the ecosystem.

### ***Education and Commitment***

Education of the public regarding the current status of the longleaf pine ecosystem, its potential economic value, its outstanding biodiversity, and the role of fire in maintaining the system is an initial step in securing support for restoration (Landers and others 1995). A primary need in this process is to promote the use of fire as an ecological force necessary to maintaining this fire-dependent ecosystem. Frequent prescribed burning, including use of growing-season fires where appropriate, promotes the diversity and stability of these communities (Noss 1989). Many private landowners are concerned about the environment and will support restoration, if through the process they generate income from their land. Longleaf pine can be managed in an ecologically sensitive manner that generates income satisfactory to interest a landowner in restoration (Landers and others 1990).

### ***Determining Success***

One way to measure the success of the restoration process is to determine through periodic forest surveys if the area in the longleaf pine type increases. Another method is to determine if the production of longleaf pine nursery stock increases in relation to the other southern pines. Some would question whether an increase in area of longleaf pine plantations equates to an increase in ecosystem restoration. Certainly it takes more than planting trees to restore the ecosystem, but it is the critical first step. Recent research indicates that the productivity of an ecosystem is controlled to an overwhelming extent by the functional characteristics of the dominant plants (Grime 1997). So, with reestablishment and appropriate management, including the appropriate use of fire, restoration processes that include development of the typical diverse understory vegetation will begin.

## **Conclusions**

Restoration of the longleaf pine ecosystem is facilitated by planting seedlings produced in containers. Planting of longleaf is required on most sites needing restoration because sites normally are being converted from agricultural crops or other pine species. Quality container stock survives better than bareroot stock on typical longleaf pine sites and the length of time seedlings stay in the grass stage is reduced. Restoration requires more than just planting of longleaf seedlings. Survival and initiation of height growth requires

the control of competition by fire or other means and careful control of the planting “chain of events.” Container stock is not as sensitive to handling problems, but still needs good site preparation, care during handling, and precision planting. Fire is an important component needed to establish and maintain the longleaf ecosystem.

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