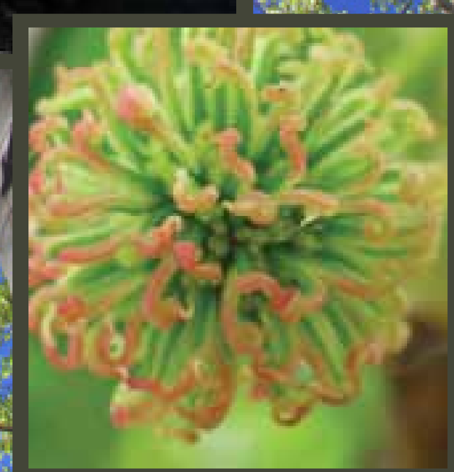
Tree Planters' Notes



United States Department of Agriculture
Forest Service

Spring 2011
Volume 54, No.1

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THANK YOU!

Dear TPN Reader

As TPN enters its 61st year of publication, there are many changes!

A new editor—I am excited to be your new editor for *Tree Planters' Notes*. I have been involved with seedling production, forest regeneration, and native plant restoration for my entire career. For nearly 20 years, I was the associate director of the Nursery Technology Cooperative at Oregon State University, where I published many articles about nursery-growing practices, seedling quality, and plant growth and survival after outplanting. In 2009, I accepted the position of Western Nursery Specialist with the U.S. Department of Agriculture (USDA), Forest Service, where I provide expert support to forest and conservation nurseries in the 17 Western States and the Pacific Islands.

A new look—As you can see, TPN has a completely redesigned cover and, for the first time, it is printed in color throughout. The use of color is ideal for publishing photographs, illustrating differences in plant health and development, and discerning zones and features on maps.

A renewed vigor—During the past 10 years, TPN was published only six times. It is my intention to get this journal back to a regular publishing schedule with two issues per year (spring and fall).

New articles—Because of the irregular publication schedule during the past decade, few authors are clamoring to submit articles. Please consider submitting your technical or research article for publication. Help me revive this long-standing resource! I have also initiated a new series of articles to highlight tree-planting efforts in each State. Guidelines for authors appear at the end of this issue and online at http://www.rngr.net/publications/tpn/author_guidelines.

New subscription process and electronic subscriptions—To continue receiving copies, you must now update your subscription to TPN online at http://www.rngr.net/subscribe. Currently, TPN subscriptions are free. I encourage you to consider switching to an electronic subscription to minimize paper consumption and printing costs. New subscriptions are also welcome.

Again, I am delighted to be the new editor for TPN. I sincerely hope you enjoy this and future issues. In addition to welcoming your articles, I welcome your comments and suggestions. Please don't hesitate to contact me at DLHaase@fs.fed.us.

Kind Regards,

Diane L. Haase

***Tree Planters' Notes* (TPN) is dedicated to technology transfer and publication of information relating to nursery production and outplanting of trees and shrubs for reforestation, restoration, and conservation.**

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Editor: Diane L. Haase

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Printed on recycled paper.

Spring 2011

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Growing Trees in Georgia

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Georgia has long been known for its lush and expansive pine forests. From Trenton to St. George, Clayton to Bainbridge, and everywhere in between, Georgia's 24 million acres of forest land reward residents and visitors alike with beauty and resources unlike any other State in the Nation—and the forests have been furnishing those gifts for a long, long time.

Early Forests

Pollen dating suggests that the pine-dominated forests of Georgia's coastal plain have been around for at least 5,000 years. Records from DeSoto's historic 16th century expedition describe open pine savannahs in north Florida and south Georgia that transition to hardwood forests in the upper piedmont region near the Georgia-South Carolina border. In the late 18th century, William Bartram, the famed botanist and naturalist, corroborated DeSoto's observations. He found pine-dominated grasslands in the lower and upper coastal plains, longleaf pine (*Pinus palustris* P. Mill.) on the drier sites, and loblolly pine (*Pinus taeda* L.) and hardwoods in the lower lands along streams and wet areas. In the piedmont, shortleaf pines (*Pinus echinata* P. Mill.) were dominant on the drier sites, and loblolly pines were associated with the more mesic sites.

Georgia's presettlement forests were shaped to a large extent by fire. Despite receiving 40 to 70 inches (1,020 mm) of rainfall each year, extended dry periods are not uncommon in Georgia, and wildfires are frequent. Studies of presettlement forests have suggested fire periodicity of 1 to 6 years in the southern part of the State. Farther north, the wildfire intervals may have been several times that long, but they still affected species composition. Fire shaped the vast pine savannahs, and the dominant tree through much of the State was longleaf pine, a fire-dependent species. Other pines and hardwoods played a relatively minor role, except in the wetter areas that, in general, were fire free.

Before the arrival of European settlers, the forests were strongly influenced by indigenous societies. Native Americans used fire for landclearing, hunting, warfare, and vegetation management. They practiced shifting agriculture by clearing a small patch of forest, farming it, and then abandoning it after the soil's fertility was depleted. DeSoto's records describe large areas of agricultural development and large areas of uninhabited wilderness that once supported Native American populations.

Since European settlement, Georgia's forests have undergone major changes. Initially, coastal forests provided the materials for shipbuilding and repair, then construction materials for early settlements. As colonization moved inland, the forests were cleared for farming purposes. Over the years, lands were cleared, farmed, abandoned, reforested, and then cleared and farmed again multiple times. Landclearing practice peaked in the Southeast sometime after the Civil War and gradually declined through the remainder of the 19th century and into the next.

Although agricultural interests cleared portions of Georgia, it was not until the late 1800s that large-scale, commercial logging moved into the Southeast, harvesting much of the virgin timber. Whether for farming or logging, by the 1920s, most of the forests of Georgia had been cut at one time or another. By the 1950s, however, large tracts of agricultural land reverted back to forests and the numbers of acres in trees began to stabilize. Since that time, the total forest size has remained fairly constant at about 24 million acres.

Today, Georgia's forests make up 67 percent of the total land area of the State, which is fairly evenly split between hardwood and pine type forests. Of the forest land of Georgia, 45 percent is pine, most of which is plantation forests located in the lower portion of the State. Upland and lowland hardwood forests comprise an additional 41 percent of the total forest, with the remaining being either mixed pine-hardwood or nonstocked forests (figure 1).

Of the land classified as commercial forest land, about 56 percent is considered family-owned forests. Forest industry companies and other corporations own 34 percent of the forest land, and the remaining land is publicly owned (figure 2). Georgia has more privately owned forest acreage than any other State.

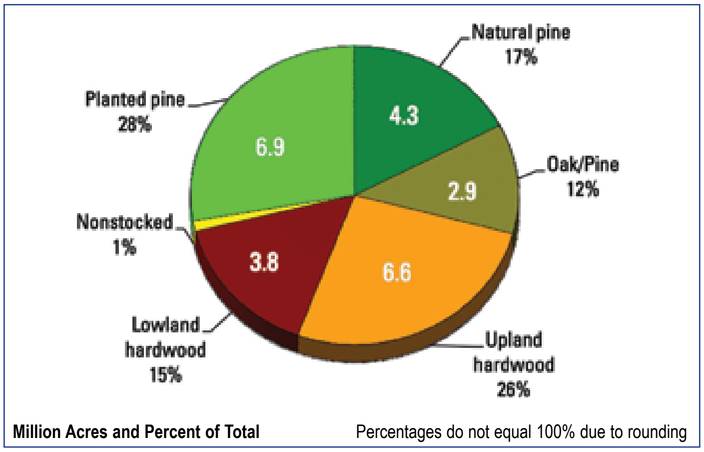

Figure 1. Area of forest land by forest type group for Georgia (Source: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis and Georgia Forestry Commission, 2008).

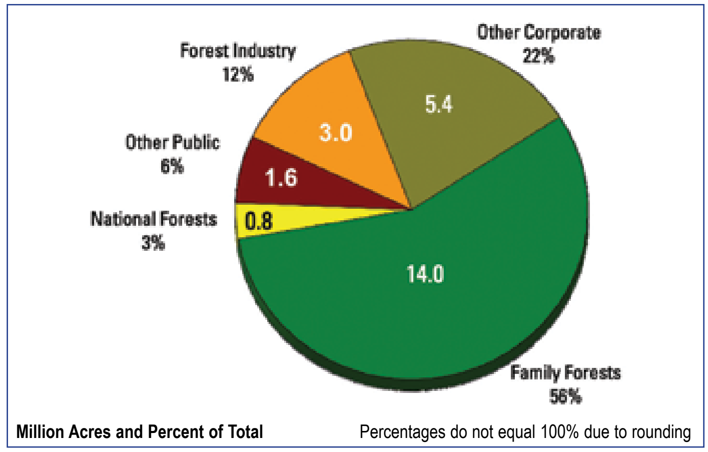

Figure 2. Ownership of forest land in Georgia (Source: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis and Georgia Forestry Commission, 2008).

Regions

Six physiographic regions in Georgia are the (1) Southern Coastal Plain, (2) Southeastern Plains, (3) Piedmont, (4) Blue Ridge, (5) Ridge and Valley, and (6) Cumberland Plateau (figure 3).

Both the Southern Coastal Plain and the Southeastern Plains regions consist primarily of slash (*Pinus elliottii* Engelm.), loblolly, longleaf pines, and lowland hardwoods. Although not necessarily the most fertile, these two regions, in general, are the most productive portions of the State with respect to forestry. They are characterized by older stands in river bottoms with younger stands on the higher ground. Active forest management is commonplace and harvesting and replanting activities account for the younger stands.

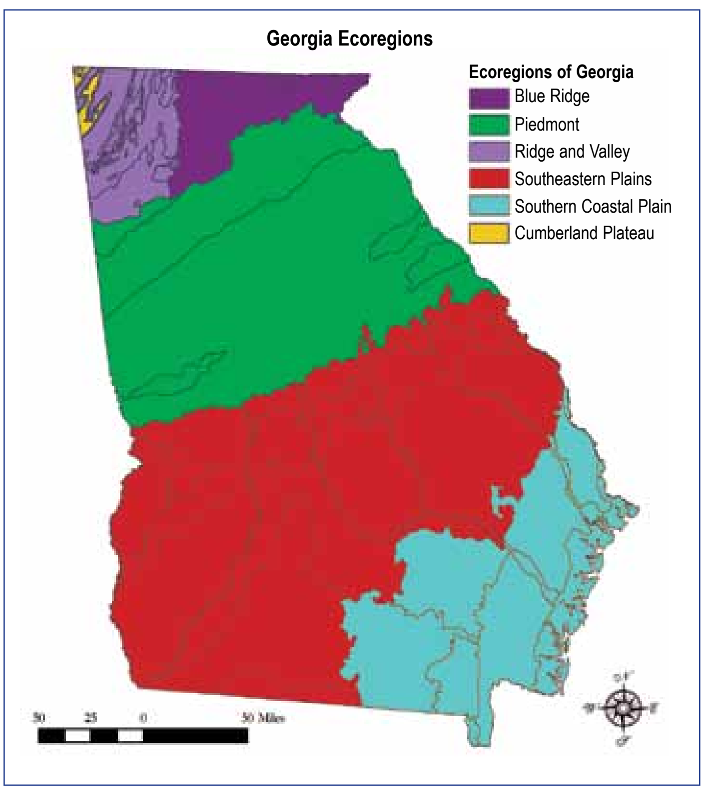

Figure 3. Physiographic regions of Georgia (Source: U.S. Environmental Protection Agency).

Moving north, the flatwoods and gentle slopes of the plains give way to the storied, red clay, rolling hills of the Piedmont region. Loblolly pine, pine-hardwood mix, and upland and lowland hardwood forests are dominant. Forest productivity tends to decline slightly in this region and the stand age-class increases. Commercial forestry is somewhat less important in this region, because much of the land usage is recreational, residential, and urban. Atlanta's sprawling cosmopolitan area dominates a substantial portion of the Piedmont.

The forests of the Ridge and Valley and the Cumberland Plateau regions are primarily upland hardwoods at the higher elevations, with loblolly and Virginia pines (*Pinus virginiana* P. Mill.) on the lower slopes and valley floors. The Blue Ridge region is characterized by upland hardwoods, with small amounts of white pine and hemlock in the narrow valleys and stream bottoms. The rugged terrain, coupled with large tracts of national forests in the Blue Ridge region, leads to some of the oldest stand age classes in the State. Forestry is noticeably less important across the northern tier of the State, although the forest's contribution to furniture, firewood, and specialty products is not insignificant.

The Forest Economy

The economic importance of forests to Georgia's economy cannot be overstated. In 2009, despite the recession, forestry generated total economic activity of more than $27 billion.

The forest products industry accounted for more than 118,000 jobs with total compensation that exceeded $5.6 billion. Only the food processing and the transportation equipment manufacturing industries were greater economic contributors than forestry in terms of wages and salaries, and only the food processing industry employed more people. The forest products industry generated $472 million in tax revenue to the State budget. Of the State's 159 counties, 44 are considered to be at least moderately dependent on the forest products industry (Riall 2010).

Georgia boasts 146 primary forest products manufacturers: 83 sawmills, 6 veneer mills, 12 pulp mills, and 45 mills that produce other products from logs. According to 2007 mill production data, Georgia leads the other 13 Southern States in total round wood, pulpwood, composite panels, and posts and pilings production. Pulp and paper products, which continue to be the leading sector, account for 65 percent of the economic activity (Schiller and others 2009).

Forest-based recreational activities also contribute significantly to the State's economy. Georgia's forests attract more than 130,000 nonresident hunters annually, and the total economic effect of recreational fishing in Georgia is estimated to be $1.5 billion. Harder to quantify, but no less real, are the contributions of Georgia's forests to clean water, clean air, urban cooling, and quality of life.

Although the traditional sectors of the forest economy remain strong, Georgia is also well positioned for future forest economic strength. The number of forested acres has fluctuated little in the past 50 years, but the productivity of those acres has increased dramatically. Today, Georgia's forests are producing 56 percent more wood annually than is being harvested, and the standing wood volume is 96 percent greater than it was in 1953 (figure 4).

Due in part to income tax credits for renewable energy generating facilities, Georgia is attracting new bioenergy production plants. Recent announcements tout the construction of 11 bioelectricity plants that will produce 700 megawatts of power. In southeast Georgia, the world's first cellulosic fuel factory is operating, converting nonmerchantable wood and harvest residues into ethanol and methanol. Ultimately, the plant will produce 100 million gallons each year from 1 million tons of biomass.

Carbon credits, too, may soon provide additional opportunities for Georgia landowners to manage healthy forests. Georgia's online Carbon Registry was recently introduced. Although the carbon market is still developing, the potential value to landowners is tremendous. In 2008, Georgia's forests grew a net gain of 546 million cubic feet of green wood, sequestering approximately 15 million tons of carbon dioxide (CO_2). This tonnage offsets more than 8 percent of Georgia's CO_2 emissions for the year, with another 12 percent of annual emissions stored in products produced from harvested stands.

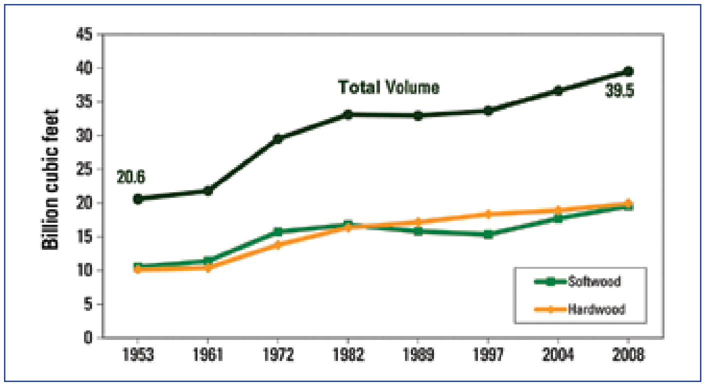

Figure 4. Standing hardwood and softwood volume of live trees in Georgia (Source: U.S. Department of Agriculture, Forest Service, Forest Inventory and Analysis and Georgia Forestry Commission, 2008).

Rigorous slash and loblolly tree improvement programs, coupled with enhanced forest management techniques, have made impressive strides. It is estimated that cooperative tree breeding programs in Georgia and across the Southeast are improving forest productivity by close to 1 percent per year. Competition control, fertility enhancement, and other plantation management tools can be even more effective. It appears that Georgia's forests have nearly limitless potential to supply renewable products and services far into the future.

Georgia's State Forestry Agency

The Georgia Forestry Commission traces its roots back to the 1921 Forestry Act, which provided for a State Board of Forestry. Initially, the board was largely advisory, providing reports to the General Assembly. By 1925, it had evolved into the Georgia Forestry Department. With partial funding from the Clark-McNary Act and an acreage fee paid by local timber protection organizations, the Georgia Forestry Department entered into cooperative forest fire protection agreements with the USDA Forest Service. Although wildfire prevention and education remained the primary efforts of the department, the State's first nursery crop was grown in 1929 with the cooperation of the University of Georgia, School of Forestry. Reorganization of State agencies in 1937 saw the Georgia Forestry Department become a division of the Department of Natural Resources. In 1949, the organization adopted its current status as the Georgia Forestry Commission (GFC), an independent agency reporting directly to the Governor's office.

Today, the GFC is a dynamic State agency with a mission *to provide leadership, service, and education in the protection and conservation of Georgia's forest resources*. The GFC employs 545 full-time personnel and an additional 137 part-time employees at 113 facilities across the State. It is organized into four departments: Fire Protection, Forest Utilization, Forest Management, and Reforestation.

The GFC's primary responsibility is statewide wildfire management on all forest land and on 3 million acres of open land. The agency has 330 tractor and plow units and 150 wildland engines at its disposal. The State averages more than 7,000 wildfires per year that burn 42,000 acres annually. Debris burning accounts for more than one-half of the fires, followed by arson and other human activity. Lightning is responsible for about 4 percent of annual wildfires in Georgia. Of the organization's legislatively appropriated budget, 80 percent is directed at fire suppression and prevention. The GFC also administers community-based mitigation programs and a prescribed-burning program to lessen the threat of wildfire to forests and communities.

The Forest Utilization Department's mission is to increase the economic viability of forest ownership and forest management by developing markets for forest resources. The department's four staff members provide information, resource monitoring, and technical assistance. Areas of emphasis include standing volume inventory, utilization rates, sustainability projections, Georgia's Carbon Sequestration Registry, Directory of Forest Products Companies in Georgia, bio-fuels, and economic development.

The Forest Management Department provides information and technical assistance to Georgia's private forest landowners to enhance their woodlands for economical, social, and environmental benefits. The service is delivered to private landowners by professional foresters, some of whom are assigned counties and deal directly with the public. Other foresters help implement and deliver regional and statewide programs, including water quality, forest stewardship and legacy, urban and wildland-urban interface, forest health, cost-share programs, and forest inventory and analysis. By statute, the GFC is authorized to take action pertaining to the nurture and culture of Georgia's forests; to monitor and suppress forest insect and disease outbreaks; and, by authority granted by the Georgia Environmental Protection Division, to monitor and investigate water quality issues pertaining to silvicultural activities.

The Reforestation Department is charged with providing high-quality, genetically improved, and regionally adapted, bare-root seedlings to Georgia landowners. To fulfill this directive, the department operates the Flint River Nursery (Byromville, GA), two seed orchards, and a seed processing and conditioning plant. The nursery offers about 15 million bare-root seedlings for sale to Georgia landowners each season (figure 5). Species include slash, loblolly, longleaf, shortleaf, and Virginia pines and a variety of hardwoods and other coniferous species. The orchards provide most of the seeds for nursery production, but some species may be supplemented by wild collections. A robust breeding and testing program, conducted in cooperation with the North Carolina State University Tree Improvement Cooperative and the Cooperative Forest Genetics Research Program, improves the growth, form, and disease resistance of all loblolly and slash pine seedlings sold from the GFC nursery. All departmental operations are accomplished without State appropriations. Revenue generated from seedling sales, seed sales, and other services must provide all departmental expenses each year.

Figure 5. The State's Flint River Nursery produces millions of bare-root seedlings annually. On the **left** is a bed of slash pine seedlings and on the **right** are cherrybark oak seedlings.

Tree Planting

The first large-scale tree planting efforts in Georgia began in the 1920s. Initial efforts to reforest cutover land and overworked agricultural fields were modest. Seedling production was less than 500,000 but trended slowly upward throughout the 1930s. Predictably, tree planting dropped during the early 1940s. After World War II, production again began to climb, hitting a peak during the Soil Bank program from 1958 through 1961. After a rapid decline, tree planting again inched upward toward an extended high during the Conservation Reserve Program of the 1980s and 1990s. Since the turn of the 21st century, the number of acres planted each year in Georgia has again declined and remains at about 230,000 acres per year (figure 6).

Loblolly and slash pines are by far the most frequently planted trees in Georgia. They are the two most commercially important species and are well suited for plantation forestry. Both pines are consistent and prolific cone producers. Their seeds are relatively easy to extract, clean, and store. The seeds have simple stratification requirements and germinate in high percentages. The seedlings grow uniformly and are amenable to management. Both species can be grown inexpensively in containers or in bare-root nursery beds. In a single season they are hardy enough for machine-lifting from nursery beds, yet small enough to be produced in large numbers. Under the proper circumstances, the seedlings can withstand lengthy storage and transportation, and they can be planted rapidly by machine or by hand with excellent results. Over the years, these two species have accounted for more than 90 percent of the trees planted in Georgia.

In recent years, the number of longleaf pine trees planted in Georgia has steadily increased. Federal cost-share money is partially responsible for the increase, but species and ecotype restoration objectives among landowner groups, such as the Longleaf Alliance and Tall Timbers, have done a great deal to encourage interest in this tree. From 2008 through 2009, 54 million longleaf pines were produced in Georgia nurseries, almost doubling the production of each of the previous two seasons.

Figure 6. Acres of trees planted in Georgia, 1975–2007 (Source: Georgia Forestry Commission data).

Hardwoods, primarily oaks, and other nonpine species account for approximately 1 percent of the State's seedling production in any given year. For the most part, hardwoods are planted for wildlife habitat and mast production. Mitigation plantings and restoration projects are also common.

Seven major bare-root nurseries and a similar number of container production facilities operate in Georgia. Smaller operations move in and out of production as demand fluctuates. Annual production from all nurseries has been falling in the past several years, but these facilities still produce about 50 percent more seedlings than are needed to meet instate planting requirements. Many of the nurseries in Georgia produce the seedlings for planting in adjacent States and across the region. Container facilities grow primarily longleaf pines, but increasingly, the best genetic materials from slash and loblolly pine breeding programs are also being grown in containers.

Challenges

Several important trends in forest ownership are likely to affect Georgia's forests and tree planting efforts in the future. First, the acreage that the forest industry in Georgia owns has shifted dramatically to "other corporate" ownerships during the past two decades. To a large degree, the vertically oriented forest industry companies have divested their forest landholdings in the State. Timber investment management organizations (TIMOs) and real estate investment trusts (REITs) have increased their share of forest acreage considerably. Exactly how the shorter investment horizons of TIMOs and REITs will alter forest management and tree planting in Georgia has yet to be determined. It is evident, however, that although TIMOs and REITs have been supportive of tree improvement and seed orchards, they are less likely to invest in the facilities necessary to advance these programs. As a result, fewer organizations are sharing the responsibilities of seed production and genetic improvement.

Second, the size of family-owned forest tracts has been declining noticeably in the past two decades. Although the total number of acres in this ownership category has remained fairly constant since the 1970s, the tract size has decreased dramatically. Currently, close to 75 percent of the forest landowners in Georgia now own parcels that have fewer than 20 acres (figure 7). Forest management on parcels of this size

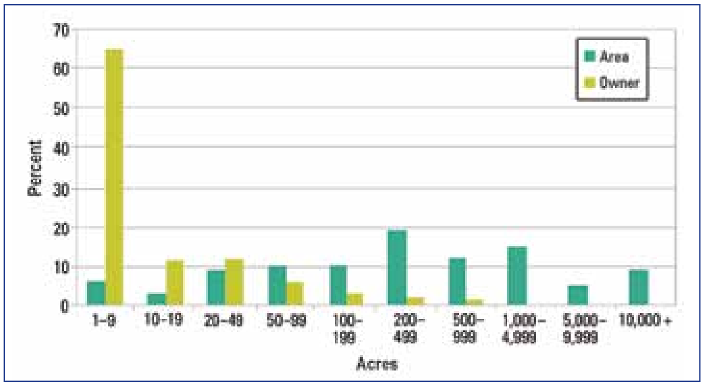

Figure 7. Percentage of forest land by tract size and owner (Source: U.S. Department of Agriculture, Forest Service, National Woodland Owner Survey, 2006).

certainly limits commercial production, but is likely to also affect the size and scope of wildlife management and ecotype restoration projects.

Third, urban land comprises about 9 percent of the State, with wildland-urban interface areas contributing an additional 9 percent. Between 1990 and 2000, the urban component of Georgia's land base grew by 32.7 percent. By 2050, this acreage will comprise 14.3 percent of the total land area of Georgia (Nowak and Walton 2005). In the first 5 years of the 21st century, the total canopy cover decreased by nearly 400,000 acres and the State added 106 acres per day of impervious surfaces. Urbanization and development will have tremendous effects on the forests of tomorrow.

Lastly, for more than 60 years, the GFC has played a major role in affecting the forests of the State. From genetic development and nursery production to landowner advice on tree planting through harvesting, fire prevention and suppression, and the marketing and utilization of wood products, the forests of Georgia have been a priority of State Government. Increasingly, the role of the State Government in forestry is being questioned and, increasingly, is being diminished. Furthermore, State funding for natural resources, in general, and for forestry, in particular, has steadily declined during the past 10 to 15 years. Ultimately, this challenge may prove to have the largest effect on tree planting and the future of forestry in Georgia.

We Grow Trees

Although Georgia's forests face a host of challenges, they have historically shown remarkable resiliency. The GFC and its committed stakeholders believe that with the wise use of knowledge and resources, Georgia can attain its vision of *healthy, sustainable forests providing clean air, clean water, and abundant products for future generations.* Georgia does one thing like no other place: we grow trees!

Several recently produced, comprehensive reports address the condition and sustainability of Georgia's forests and strategies for their conservation. Those reports are available at http://www.GaTrees.org, the Georgia Forestry Commission Web site. The site also provides wide-ranging information about Georgia forestry, the GFC, and the agency's myriad services.

References

NOTE: Much of the information contained in this article is from GFC data as described in "Statewide Forest Resources Assessment and Strategy" available online at http://www.gfc.state.ga.us/ForestManagement/GAForestResourceAssessmentStrategy.cfm.

Nowak, D.J.; Walton J.T. 2005. Projected urban growth and its estimated impact on the U.S. forest resource (2000–2050). Journal of Forestry. 103(8): 383–389.

Riall, B.W. 2010. Economic benefits of the forestry industry in Georgia: 2009. Enterprise Innovation Institute Report. Georgia Institute of Technology. 21 p.

Schiller, J.R.; McClure, N.; Willard, R.A. 2009. Georgia's timber industry—an assessment of timber product output and use, 2007. Resour. Bull. SRS-161. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 35 p.

Tree Planting in Indiana

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Early Indiana Forestry

In the past 100 years, Indiana has been brought back from the brink of complete deforestation through tree planting supported by the State's nursery program. Indiana's nursery program began at the turn of the 20th century and has enjoyed a productive and successful history.

By 1900, Indiana had become the country's number one producer of hardwood lumber and forest products (Himebaugh 2001). Indiana's favorable climate and productive soils made the State's land ideal for agricultural use. Loss of forest cover to timber harvest and landclearing for agriculture and settlement led to serious soil erosion, siltation of streams and lakes, and a shortage of timber. Forest cover in the State had plummeted from 87 percent at presettlement to less than 10 percent in 1900. In 1901, Governor Winfield Durbin established the Division of Forestry within the State's Department of Natural Resources and, in 1903, purchased 2,000 acres of degraded, cutover land for establishing the Clark Forest Reservation, located outside of Henryville (O'Connor 2003). Early Indiana foresters, who "hit the ground running," used the Clark Forest Reservation to conduct tree-planting research and established a 15-acre seedling nursery for their own use. By 1907, tree seedlings were available for public distribution (Himebaugh 2001).

Native deciduous species, such as black walnut (*Juglans nigra* L.), hickories (*Carya* spp. Nutt.), and oaks (*Quercus* spp. L.), were planted in these early years (Guthrie and Gladden 1916). Many were not well suited, however, for establishment on the heavily eroded sites that were in need of reforestation. Emphasis gradually shifted to species that could fix nitrogen levels, such as black locust (*Robinia pseudoacacia* L.) and white pine (*Pinus strobus* L.), and species that were well adapted to poor soils, such as red pine (*P. resinosa* Soland.) (Jackson 2001). The idea was to return the soil to a productive condition that would support a deciduous forest (Anonymous 1941). As anticipated, the native deciduous species naturally seeded into the pine and locust mix of these early plantings and gradually returned the species composition to one of mixed hardwoods. As more productive sites became available for planting, emphasis returned to planting native deciduous species, starting with white ash (*Fraxinus americana* L.), sycamore (*Platanus occidentalis* L.), and yellow-poplar (*Liriodendron tulipifera* L.).

Each time new parcels throughout the State were brought under State management, the Division of Forestry established a temporary nursery. These nurseries supplied seedlings for planting on the parcel and on the land of local landowners. More than 1 billion seedlings have been planted for public and private conservation projects in Indiana since the advent of the State's nursery program.

Current Forestry in Indiana

Today, about 4.7 million acres of forested land in Indiana (figure 1) amount to a fairly stable 20 percent of the State's land base (Bratkovich and others 2004). About 3.9 million acres, or 83 percent of the State's forested land, are privately owned by about 190,000 landowners. The remaining forested land is under public control in the jurisdiction of various Federal, State, and local agencies (table 1).

Figure 1. Forest land in Indiana (*Source: Indiana Division of Forestry).*

Table 1. Forest land in Indiana under public ownership.

Agency	Forested acres	Managed for timber
DNR Fish and Wildlife	83,100	No
DNR Forestry	148,607	Yes
DNR Nature Preserves	16,034	No
DNR Outdoor Recreation	3,779	No
DNR Historic Sites	723	No
DNR Parks and Reservoirs	57,199	No
DNR Other	66	No
IDOC (Corrections)	1,989	Yes
Federal Lands (Forest Service)	412,248	Yes

DNR = Department of Natural Resources. IDOC = Indiana Department of Corrections.

Since most of the State's forest land was planted or regenerated after 1900, most of it has reached the same seral stage. The oak-hickory forest type is predominant in Indiana and is the forester's preferred species mix. High-value black walnut (*Juglans nigra* L) and black cherry (*Prunus serotina* Ehrh.) are in high demand for fine furniture, but the oak family (*Quercus* spp. L.) is the workhorse of the State's hardwoods group and supports Indiana's furniture industry. Hickory (*Carya* spp. Nutt.), too, is seeing unprecedented growth in use for cabinetry and flooring, although it remains an important wildlife habitat and food species of the standing forest. Unfortunately, these shade-intolerant species are not effectively regenerating under the shade of the mature forest. The understory primarily consists of shade-tolerant species such as sugar maple (*Acer saccharum* Marsh) and beech (*Fagus grandifolia* Ehrh.). Studies, such as the multiagency Hardwood Ecosystem Experiment (HEE), are under way to find ways to encourage natural regeneration of the preferred species. This study covers long-term, forest-level interactions of various management regimes and is expected to run for 100 years. At this point, however, the only reliable regeneration method is replanting after harvest.

Seedling Production

Currently, the Indiana Division of Forestry operates two tree seedling nurseries. The Jasper-Pulaski State Nursery is located approximately 100 miles (160 km) northwest of Indianapolis and operates as a seedling distribution and seed-buying center for the northern half of Indiana. The Vallonia State Nursery (figure 2) is located about 80 miles (130 km) south of Indianapolis and handles all seedling production and seed-buying and distribution for the southern half of the State.

During the 1980s, three factors combined to necessitate an expansion of the nurseries' production capacity. First, increased funding for USDA Conservation Reserve Program planting was included in the Federal farm legislation. This increased funding for planting led to a large increase in demand for seedlings. Second, the heaviest demand shifted from conifers to hardwoods. This shift was driven by an increase in the value of hardwood timber and a shift to planting in areas with more productive soils that could support the growth of hardwoods. Third, customers demanded larger seedlings that could out-compete weeds on the more fertile planting sites and survive herbivore predation. Not only were the nurseries challenged to grow many different species, but they also faced the challenge of producing significantly larger seedlings at a reasonable cost. These seedlings had to be able to withstand competition from deer browsing, floods, droughts, and competing vegetation (figure 3).

In the early 1970s, average seedbed densities were in the range of 25 seedlings per square foot. Today, seedbed density averages about 5 seedlings per square foot in the State nurseries, where quality is equal in importance to the total number produced. Currently, the nurseries produce 52 species of bareroot conifer and hardwood seedlings annually. The primary stock type produced is 1-0, although 2-0 and 3-0 components also are produced. Total production at both nurseries peaked at 7 million seedlings in 1991 but fell back to between 4 and 5 million seedlings annually during the mid-1990s (table 2). Present annual production is approximately 3.5 million seedlings.

Figure 2. Seedlings growing in beds at Vallonia State Nursery.

Figure 3. Mowing between planting rows **(left)** actually encourages denser weed growth. Herbicide use within the planting rows **(right)** is best for planting success.

Table 2. Seedlings sold and acres planted in Indiana for the past decade.

Year	Total seedlings sold	Acres planted*
2000–2001	5,792,044	9,653
2001–2002	5,334,513	8,890
2002–2003	4,744,445	7,907
2003–2004	5,855,558	9,759
2004–2005	5,193,997	8,656
2005–2006	4,665,627	7,776
2006–2007	4,816,107	8,026
2007–2008	3,675,983	6,126
2008–2009	3,532,005	5,886
2009–2010	3,229,842	5,383

*Assume 600 stems per acre.

The nursery program's goal is to produce high-quality seedlings that will ensure good outplanting survival. Therefore, the nurseries emphasize the various cultural practices known to lead to the highest quality seedlings. Thorough seed testing, seedbed planting density, scheduled fertilization, and proper pest control are all integral components of raising high-quality seedlings. Most of the seeds planted in the nursery are collected from native stands within the State. This ensures that the seedlings will be acclimated to Indiana's growing conditions. Seed collection is geared toward the demand seen today and predictions for what the future might hold. Predicting future demand for tree species is difficult at best. Looking at historical trends and current demands gives the best indication of future needs.

Nursery customers generally fall into one of six broad categories (figure 4) as described in the following sections.

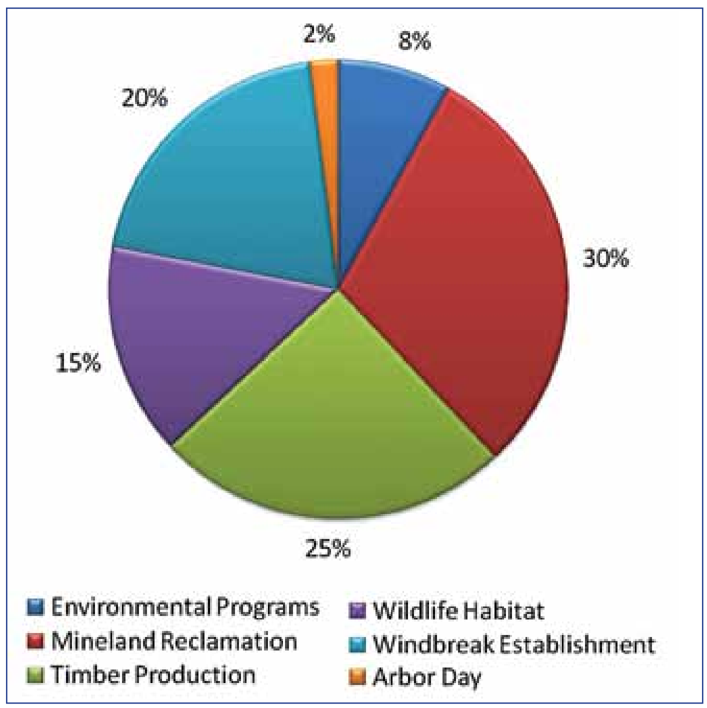

Figure 4. Who we serve—customer base for the Indiana State nurseries.

Timber Production

Indiana's current productive timber land came about as the result of tree planting in the early days of the Division of Forestry. According to our annual customer surveys, about 25 percent of current planting is specifically intended for timber production. Much of the rest, although planted with other goals in mind, will also provide productive timber land for future generations.

Mineland Reclamation

Indiana's Division of Reclamation originated as part of the Division of Forestry; therefore, it is familiar with the long-term benefits of tree planting. Mining companies are required to return the postmining land to its approximate original contour and to its premining land use. Reclamation of surface coal mines (figures 5 and 6) is a significant use for Indiana's nursery seedlings. Many of the species the State nurseries offer for sale are adapted to grow in the poor soils often found in reclamation sites.

During the past 10 years, 28,572 acres of active mine lands were reclaimed as forest land or wildlife habitat through the planting of nursery seedlings. Another 2,900 acres of previously abandoned surface mines were also reclaimed in that period.

Wildlife Habitat

About 15 percent of current planting is specifically intended to benefit wildlife. Many landowners keep wildlife in mind when designing their plantings. From birds to deer, landowners love to attract animals to their property for viewing. The nurseries assemble mixed species seedling packets each year, which are designed to provide food and cover for an array of wildlife species. In recent years, offerings have included "songbird," "wildlife," "quail," and "nut" packets.

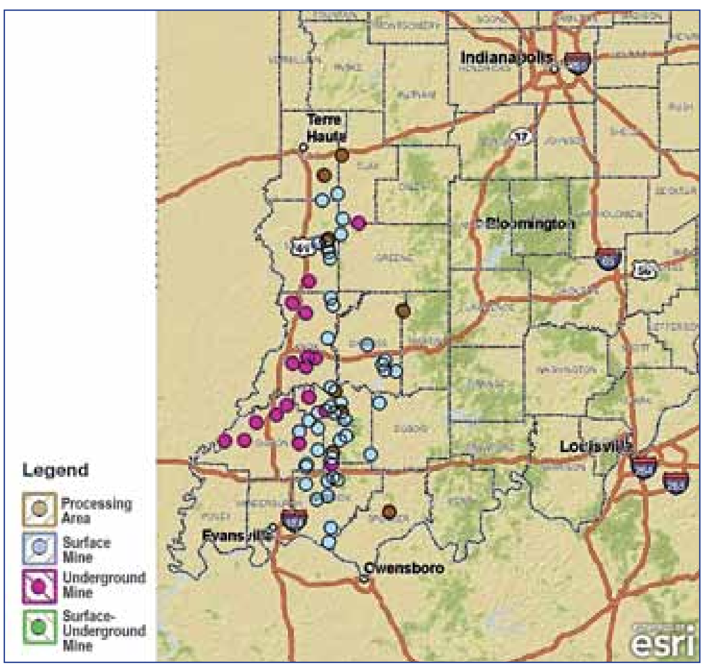

Figure 5. Surface mine locations in Indiana (*Source: Indiana Division of Reclamation).*

Environmental Programs

Environmental programs administered by the U.S. Department of Agriculture, such as the Conservation Reserve Program, the Wildlife Habitat Incentive Program, the Wetland Reserve Program, and the Conservation Reserve Enhancement Program, are also heavy users of the nurseries' seedlings and accounted for 1,442 acres planted just during 2010. These environmental programs can fluctuate with changing administrations, which has a significant effect on the number of acres planted each year.

Windbreak Establishment

High winds in northern Indiana can contribute to wind erosion and convective cooling. The terrain in that part of the State is very flat and subject to such high wind that several large, new wind energy farms have been established. Therefore, windbreak establishment, primarily in the northern part of the State, is an important use of our nurseries' conifers.

Landowners typically plant 100 to 1,000 seedlings for a windbreak or small wildlife planting and usually do their own hand planting. Larger plantings are normally contracted with a local consulting forester (figure 7), although some Resource Conservation and Development programs have tree planters available to loan for short-term use.

Figure 6. Heavy-duty equipment is used to plant seedlings on mine reclamation sites.

Figure 7. Established reclamation planting.

Arbor Day

Every year since 1990, the nursery program has offered a free seedling to all third grade students across the State in celebration of Arbor Day. Promoting tree planting to children at a young age is a way to demonstrate the importance of planting trees and the associated benefits provided to the environment. Various other organizations that celebrate Arbor Day also receive free seedlings from the nurseries for their Arbor Day programs. This effort, which reaches a wide variety of constituents, promotes the benefits of tree planting.

Future Outlook for Tree Planting in Indiana

The Indiana nursery program anticipates steady seedling demand as long as cost-share programs remain at current levels. Tree planting in the State has always been closely tied to Government cost-share programs, although trees often seem to have a lower priority than other components of the Federal farm bill. Previous years' loss of cost-share monies led to an almost 50-percent reduction in seedling sales.

References

Anonymous. 1941. Shortage of spring planting stock is predicted as tree orders are filled. Outdoor Indiana. October: 8.

Bratkovich, S.; Gallion, J.; Leatherberry, E.; Hoover, W.; Reading, W.; and Durham, G. 2004. Forests of Indiana: their economic importance. NA-TP-02-04. U.S. Department of Agriculture, Forest Service, Northeastern Area, State and Private Forestry. 18 p.

Guthrie, W.A.; Gladden, E.A. 1916. Sixteenth annual report of the State Board of Forestry. Indianapolis, IN: Indiana State Printing Board. 217 p.

Himebaugh, N., ed. 2001. The Division of Forestry: our first 100 years. Indianapolis, IN: Indiana Department of Natural Resources, Division of Forestry. 104 p.

Jackson, M.T. 2001. Indiana's State tree nurseries: a vital resource. Unpublished manuscript. 5 p.

O'Connor, P.A. 2003. Clark S.F.–The Early Days. Informational pamphlet. 23rd Annual Central States Forest Soils Workshop, October 14–16, 2008. Vallonia, IN: Indiana Division of Forestry. 5 p.

An Overview of Rural Forestry Tree Planting in North Dakota

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North Dakota is largely a rural State with an economy that is deeply rooted in agriculture. The State's long history of tree planting efforts dates back to the Timber Culture Act of 1873. Early settlers planted trees to provide wind protection, fuel, and food. The Dust Bowl of the 1930s had far-reaching social, economic, and environmental consequences, which accelerated tree planting programs. The most notable program was the Prairie States Forestry Project, which resulted in the planting of 217 million trees in the Great Plains. Tree planting efforts have continued throughout the State into present times.

North Dakota is often characterized as a prairie State because of the topography, soils, and climate that promote perennial grasses and forbs and limit the natural distribution of forest land. Despite this characterization, some diverse and unique forest resources are found in the State. Upland forests (including deciduous and coniferous forests and wooded shrub lands), riparian forests, and rural tree plantings encompass 1,958,000 acres. In addition, community forests include boulevard trees, city park trees, and trees that occur naturally within city limits and rights-of-way. Nearly 70 percent of forest land in the State is privately owned (figure 1) (Haugen and Kangas 2007).

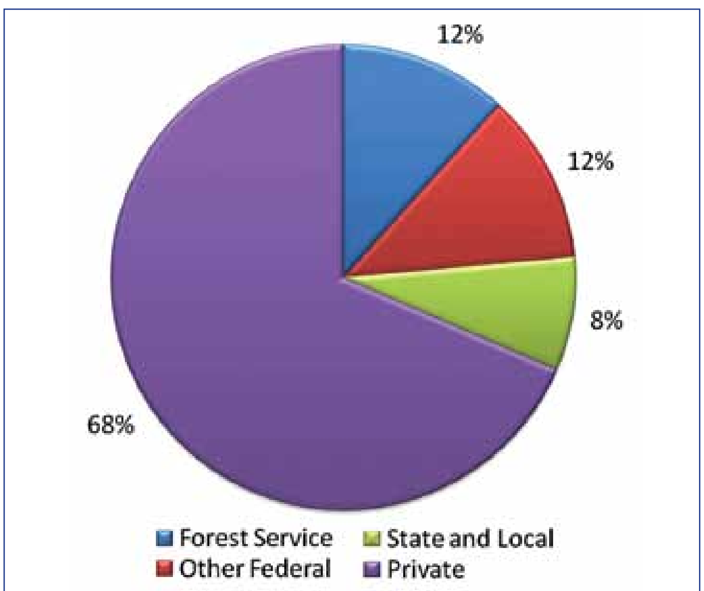

Figure 1. Ownership of forest land in North Dakota.

State Forestry Program

The North Dakota Forest Service is organized under the North Dakota Board of Higher Education. A State forester, who reports to the President of North Dakota State University at Fargo, administers the agency. The land-grant mission is to "care for, protect, and improve forest and natural resources to enhance the quality of life for present and future generations." The agency maintains nine office locations in the State and is organized around three programs, each of which is led by a team leader. The Forestry and Fire Assistance Team focuses on fire protection, assistance to community forests, forest stewardship for landowners, and forest health to minimize invasive pathogens and other pests. The Nursery and State Forests Team manages the State forestry nursery and the State's five forests (encompassing 13,000 acres). The Administration Team provides information, education, and administrative services.

Upland Forests

Upland forests (figure 2) can be found throughout the State but are more prevalent in the eastern and northern areas (figure 3). The most common deciduous upland forest types in North Dakota include the aspen/birch (*Populus tremuloides* Michx./*Betula papyrifera* Marsh.) and bur oak (*Quercus macrocarpa* Michx.) forest types.

Only 2 percent of the State's forest land is classified as western conifer forests. Isolated stands of ponderosa pine (*Pinus ponderosa* P. & C. Lawson) and limber pine (*Pinus flexilis* James) are located in the southwest counties of the State. In addition, approximately 600,000 acres of Rocky Mountain juniper (*Juniperous scopulorum* Sarg.) shrub lands grow in the Badlands of western North Dakota.

Figure 2. Upland forest in northeastern North Dakota.

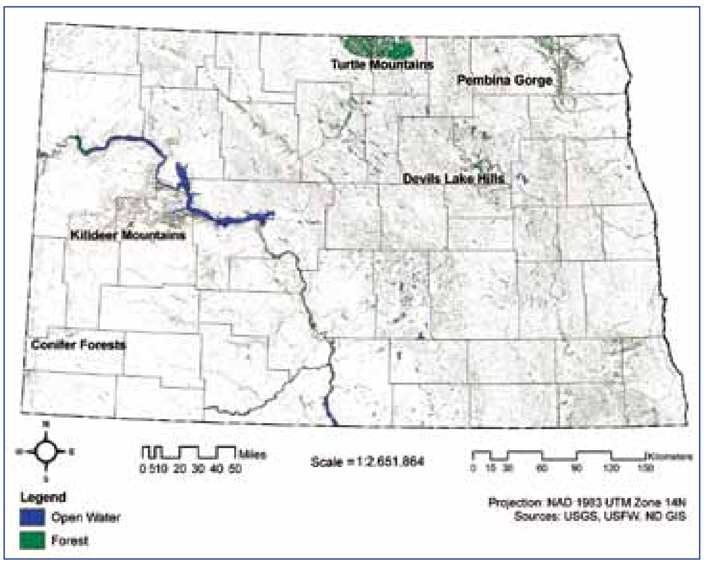

Figure 3. Distribution of upland forests in North Dakota.

Riparian Forests

The elm/ash/cottonwood forest type is the most abundant of all forest types in North Dakota and occurs along rivers, lakes, and streams. In eastern North Dakota, riparian forests are often associated with sites that have deep, alluvial soils at the base of slopes. These forest sites are often present in coulees that were formed by glaciation and water erosion. Thick layers of organic matter are common in the deep soils of these areas. Species such as green ash (*Fraxinus pennsylvanica* Marsh.), box elder (*Acer negundo* L.), and basswood (*Tilia Americana* L.) may dominate along the eastern rivers, although cottonwood (*Populus deltoids* Bartr. ex Marsh.), ash, and box elder may be more common to the west. Other associated tree species include American elm (*Ulmus americana* L.), hackberry (*Celtis occidentalis* L.), bur oak, and willow (*Salix* spp.). Associated shrub species include chokecherry (*Prunus virginiana* L.), gooseberry (*Ribes* spp.), and snowberry (*Symphoricarpos* spp.).

Forestry and Conservation Nurseries in North Dakota

When the early settlers came to North Dakota during the mid- to late 1800s, trees were so scarce on the prairies that homes were constructed from sod and heated with buffalo chips. The limited forest resources in the State served as motivation for homesteaders to plant trees for fuel, building materials, fencing, and protection from the harsh environment of the Northern Plains. When North Dakota became a State in 1889, the State constitution authorized a State School of Forestry to assess tree and shrub species suitability and identify appropriate planting techniques. The community of Bottineau was selected as the site for the school due to its close proximity to the Turtle Mountains, the largest contiguous tract of forest land in the State.

Following passage of the North Dakota State legislature's Forest Nursery Act in 1913, the first forest tree nursery was opened in Bottineau in 1915. In 1951, the North Dakota Forest Service, which operated the nursery, moved it to its present location in Towner (north-central North Dakota) on a site that the U.S. Department of Agriculture (USDA), Forest Service previously occupied. The Towner State Nursery has been continuously operating ever since. The 160-acre facility is the only conifer seedling nursery in the State and produces 1.2 million trees annually (figure 4). The nursery grows both bare-root and container stocktypes. Trees that are produced to meet the needs of North Dakota citizens are used primarily in shelter belts, living snow fences, and other conservation plantings. Most trees are sold to the North Dakota Soil Conservation District, which is administered by the USDA Natural Resources Conservation Service and which offers a variety of cost-share programs to landowners.

In addition to the conifer stock produced in the nursery in Towner, deciduous conservation stock is produced at the Lincoln-Oakes nurseries. The Lincoln unit had its beginning in the early 1930s as the Mandan Nursery, under the supervision of the Bureau of Plant Industry. It was both a production nursery and a plant-testing facility. In 1935, the nursery was transferred to the Soil Erosion Service, which, 1 month later, became the Soil Conservation Service. At that time, the Mandan Nursery was moved to an area between Bismarck and Mandan and was renamed the Heart River Nursery. The Soil Conservation Service moved it to its present location on the parade grounds of the Fort Lincoln Military Post just south of Bismarck. In 1953, when the USDA discontinued all Soil Conservation Service nurseries, the North Dakota Association of Soil Conservation Districts agreed to assume the operation of the 355-acre Fort Lincoln unit. The Oakes unit of the Lincoln-Oakes nurseries was started in the late 1930s by the USDA Forest Service, south of Oakes, ND. It was closed from 1942 through 1947, until it was purchased by the North Dakota Association of Soil Conservation Districts. The 180-acre nursery has been in operation since.

Figure 4. The Towner Nursery produces more than 1 million conifer seedlings annually.

Rural Tree Plantings

Rural tree plantings throughout North Dakota generally refer to farmstead plantings, shelter belts, living snow fences, wildlife plantings, riparian buffer strips, and others that are designed to achieve conservation, economic, and societal goals. For example, field windbreaks reduce soil erosion during years of drought, reduce water evaporation from adjacent cropland, and increase crop yields (figure 5). Foresters estimate that 55,000 miles of windbreaks have been planted in the State to date. Some plantings are designed to stabilize riverbanks, filter water runoff from adjacent agricultural lands, provide wildlife habitat, protect stretches of highways prone to severe snow accumulation, provide wind protection for livestock, or protect farmsteads and rural homes from snow and wind. Although many conservation tree plantings occur in areas where the historical vegetation type was prairie, these resources are critical for the present needs of rural residents who live in the current agricultural landscape. Tree species for rural plantings in most areas of North Dakota need to be drought tolerant and cold hardy.

Harvesting and planting in State forests is limited; timber is not a notable revenue source for the State. These forests are primarily native deciduous trees and are managed primarily for recreation and wildlife habitat. Natural regeneration (e.g., root suckers from aspen) is adequate in most cases. On occasion, over-mature stands are cut back to promote native species composition in the forests. With the absence of fire or other disturbances, stands can reach a pathological rotation age. As the trees die out, brush species such as beaked hazel (*Corylus cornuta* Marsh.) can become dominant. The North Dakota Forest Service plans to study succession of aspen in the Turtle Mountains (where the largest State forest is located) by assessing various successional scenarios, which will ultimately assist with future management decisions.

Figure 5. Windbreaks planted among crop fields to protect against soil erosion and desiccating winds.

References

Haugen, D.E.; Kangas, M. 2007. North Dakota's forest resources, 2006. Research Note NRS-5. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 4 p.

Seed Maturation, Flower Receptivity, and Selfing in Sweetgum *(Liquidambar styraciflua* L.)

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Abstract

We evaluated sweetgum trees at two Oklahoma locations to determine when their seed matured, when female flower receptivity peaked, and if they would self-pollinate. Sweetgum seed reached full maturity by the second week of November, female flowers were receptive within 7 days following emergence from the buds, and receptivity peaked within 2 to 3 weeks. A green dulling to slight yellowing of the seed balls can be indicative of mature seed. Calendar date (e.g., second week of November, depending on latitude) is a better measure of maturity, however, because the color changes can be very subtle. Seed balls may be harvested as early as mid-September with a minimal loss in seed germination. Sweetgum does not easily self-pollinate, if at all.

Introduction

Sweetgum (*Liquidambar styraciflua* L.) ranges in location from Connecticut to northern Florida and westward to Missouri, Oklahoma, Arkansas, and northeast Texas. Sweetgum also occurs in scattered locations in central Mexico, Guatemala, El Salvador, Honduras, and Nicaragua (Kormanik 1990). Sweetgum is a common bottom-land hardwood of the Southeast United States. The largest trees of this species occur in the lower Mississippi River Valley (Kormanik 1990), reaching mature heights of 45 m (148 ft) and diameters of 1.2 m (3.9 ft) (Brown and Kirkman 1990). The wood of sweetgum is used for pulp, lumber, and veneer. The seeds are excellent food for birds, squirrels, and chipmunks (Kormanik 1990; Bonner 1974).

Sweetgum shows little variation in seed germination rates, seedling growth, and morphology across its wide geographic range (Bonner 1974). Sweetgum is monoecious; that is, male and female flowers are separate, but on the same tree. Across sweetgum's natural range, the male and female flowers develop from March until May. The pistillate flowers produce spherical fruiting heads that later form 22 to 35 mm diameter seed balls, which are a multiple of two-celled woody capsules (Bonner 1974).

Sweetgum trees produce viable seed crops when they reach 20 to 30 years of age (Bonner 1974). Sweetgum trees can continue seed production every season until they are at least 150 years of age (Kormanik 1990). During seed maturation, the moisture content inside the seed ball drops dramatically, the capsules open, and winged seeds disperse. For seed collection purposes, Bonner (1974, 1987) and Dirr and Heuser (2006) suggest sweetgum seed will be mature when the seed balls begin to change color from bright green to a dull yellow or light brown from September to November. Following collection, the seed balls should be dried completely to ensure the seeds will fall out or can be easily extracted. The seed balls may be dried indoors in 7 to 10 days or outdoors in about 3 to 5 days (Bonner 1987). Under normal conditions, 35 liters (1 bushel) of seed balls yield approximately 365 g (0.8 lb) of clean seed. The number of seeds in 454 g (1 lb) of seeds averages around 82,000 (Schopmeyer 1974). Seed soundness, suggesting seed quality and viability (Hartmann and Kester 2002), is usually around 80 to 90 percent in a good seed year (Kormanik 1990).

Under favorable climatic conditions, sweetgum disseminates an average of 56 viable seeds per seed ball, but only 7 or 8 seeds under the poorest conditions (Kormanik 1990). Seed dispersal is quite variable for sweetgum. The maximum dispersal distance is approximately 183 m (600 feet), but sweetgum seeds move an average of 61 m (200 feet) from the point of release (Fowells 1965).

Sweetgum seed has a shallow dormancy (Nikolaeva 1967), meaning the seed may germinate after it has been in cool, dry storage for some extended period of time (Evans and Blazich 1999). Simple pregermination treatments will enhance the percent and uniformity of sweetgum seed germination, however. One such treatment is stratification in moist media at 3 to 5 °C (30 to 41 °F) for 2 to 4 weeks (Bonner 1987). The seed can also be placed in an aerated water bath for 14 to 20 days at a constant 3 to 5 °C (38 to 41 °F). If seed have been in storage for an extended time, the stratification period can be lessened.

An optimum sweetgum seed germination testing protocol is night temperatures of 20 °C (68 °F) for 8 hours and day temperatures of 30 °C (86 °F) for 16 hours (AOSA 1993). Light is not necessary for germinating stratified seeds (Bonner and Gammage 1967). Tetrazolium staining (Bonner and Gammage 1967), radiography (Belcher and Vozzo 1979), and the excised embryo method (Bonner and Gammage 1967; Flemion 1948) are all good tests to determine seed viability. The germination of sweetgum seed is epigeal, meaning the cotyledons emerge above the surface of the soil after germination (Schopmeyer 1974; Hartmann and Kester 2002).

In spite of the amount of information available regarding sweetgum seed, we were unable to find any information describing the identification of or the timing associated with peak receptivity of the female flowers. In addition, in relying on Bonner's (1987) suggestion of collecting the seed balls when they change color from bright green to a dull yellow or brown, we lost seed in the fall waiting for the seed balls to start to show a color change. We thought we needed clarification of, or a better description of, this color change. We also wondered if sweetgum would self-pollinate. Consequently, we initiated a study with three objectives: to determine (1) when sweetgum seed matures within the seed balls and how this point of maturity can be visually observed, (2) when sweetgum female flowers are receptive for pollination in the spring, and (3) if sweetgum can self-pollinate.

Materials and Methods

We selected sweetgum trees at two locations in Oklahoma for this study. The Stillwater location (central Oklahoma) is outside the natural range of sweetgum but has a considerable number of relatively young sweetgum trees planted as ornamentals. The Idabel location (southeast Oklahoma) is within the natural range of sweetgum with many mature trees present. At each location, we selected four trees as the research trees where seed balls would be bagged and collected. The only criteria for tree selection were accessibility and sexual maturity.

The Maturation Question

To address our first objective, we collected two seed balls from each tree at the Stillwater location on August 11 and August 21, and at Idabel on August 13 and 28, and then every Monday from September 1 through November 24, 2008 (collection day occasionally varied by a day due to weather). Seed balls were observed and photographed weekly on the selected trees to look for color changes and to watch for natural capsule opening. We placed the two seed balls collected weekly from each tree in a prelabeled bag and returned them to the laboratory. The seed balls were then transferred to glass beakers, allowed to air dry for 2 weeks, returned to plastic bags, and placed in a 4 °C (40 °F) walk-in cooler (Percival Modutrol Controlled Systems, Boone, IA) for storage until the end of November 2008. When collection was completed, the seeds were counted, soaked overnight in water, and stratified by placing the moist seeds inside pre-labeled plastic bags in the walk-in cooler at 3 to 5 °C (30 to 41 °F) for 4 weeks. We then removed the seeds from stratification and germinated them on moist filter paper in Petri dishes in growth chambers, for 8 hours in the dark at 20 °C (68 °F) and for 16 hours of light at 30 °C (86 °F). We counted seeds and recorded them as germinated when the emerging radicle was at least 5 mm long.

The Receptivity Question

To answer our second objective, we placed 20 pollen exclusion bags on branches of each of the four trees at each location as soon as the female flowers were visually distinguishable. We placed the pollen bags on the trees on March 24, 2008, at the Idabel location and on April 4, 2008, at the Stillwater location. In addition, we labeled two branches with seed balls but did not bag them until 3 days later. Each pollen bag had one or more female flowers; we removed any male flowers before the branch was placed in the bag. Pollen flight after bagging was noted by day 3 at Idabel and day 4 in Stillwater. All eight trees were shedding pollen by day 8. Pollen flight lasted 14 days or less for any individual tree.

The selected trees were visited every third day (occasionally plus or minus 1 day because of weather). At each visit, we removed two bags and placed bags on branches that had bags removed 3 days earlier (except for the first revisit when the two labeled but unbagged branches were bagged). Thus, only two branches were exposed to potential pollination during each 3-day period. Each day that bags were removed, pictures were taken of the female flowers. Three days after the last sets of bags were removed for pollination, we removed all bags from all branches on April 28, 2008, at Idabel and May 6, 2008, at Stillwater. On October 23, we collected all seed balls from bagged branches of all four trees at both locations and noted any missing or aborted seed balls. Collected seed balls were placed in prelabeled plastic bags and brought to the laboratory to dry, extract, and count the seeds. We used the same stratification, germination, and counting protocols described above.

The Selfing Question

For our third objective, we placed two bags on each tree on March 24, 2008, for Idabel and April 4, 2008, for Stillwater. These bags contained both female and male flowers and remained on the trees for the entire pollen flight period. We removed these bags on April 28 at Idabel and May 6 at Stillwater. The self-pollinated seed balls were collected on October 23, placed in prelabeled plastic bags, returned to the laboratory, and subjected to the same extraction, stratification, and germination protocols previously described.

Results and Discussion

Objective 1: The Maturation Question

Figure 1 presents the average number of seeds per seed ball. Tree number 2 from the Stillwater location was removed because this tree was discovered to be dying and many of the seed balls aborted. Only the first two data points were available from the Idabel location because seed balls were mistakenly collected only for the two August dates. For these dates at the Idabel location, however, 68 and 60 seeds per seed ball were found from the first and second collection dates, respectively. The average seed yield for the Stillwater trees was less than 20 seeds per seed ball for the two August collection dates. Clearly, seed yield is set by August. The lower seed yield at the Stillwater location likely reflects the limited number of trees and thus a limited pollen cloud on the Stillwater landscape, where the only sweetgum trees are planted as ornamentals.

Percent germination across collection dates at the Stillwater location showed zero germination for the mid-August collection, and then a variable, but generally increasing germination percent through November (figure 2). At Idabel, percent germination for the August 13 and 28 collection dates was 35 percent and 71 percent, respectively. These limited data from Idabel trees suggest that seed maturation was occurring, and was ahead of seeds collected at the Stillwater location, but not complete during August. The data also support Kormanik's (1990) estimate that sweetgum can average about 56 viable seeds per seed ball under favorable conditions.

Although seed yield is set by August, the seed is not yet fully mature until mid-November. Seed balls may be harvested as early as mid-September, however, when seed is at an early maturation stage and germination will be high. These results support Michael Cunningham's (personal communication with ArborGen, LLC, in 2008) suggestion of collecting seed balls about the same time seed orchard loblolly pine cones are collected, which is early October in Oklahoma. Collection timing will, of course, vary by location.

In mid- to late September, when seed balls were in the early maturation stage, the seed balls were still fairly bright green, with little sign of color change (figure 3). For early collections, the date rather than the color might be a better indicator of the optimum time to collect. By early to mid-November, when the seed were fully mature, the bright green of the seed balls faded to shades of dull green to yellow-brown (figure 3), such that seed ball color may be an indicator of seed maturity at this stage. These results agree with Bonner (1974) and Dirr and Heuser's (2006) results that color change to shades of light green to brown is an indicator of full maturity. The color change can be quite subtle (figure 3), however, particularly in the absence of photos of earlier observations for comparison. This subtle change explains why we lost seed in the past while waiting for an obvious color change. The documented maturity date may be the more reliable indicator of the optimum time to collect sweetgum seed.

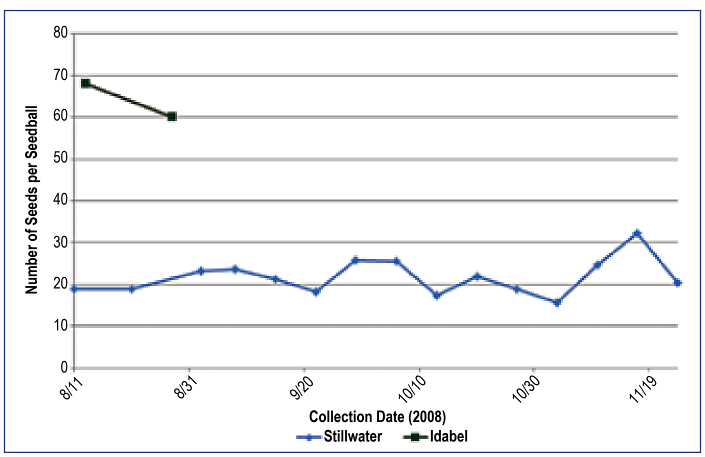

Figure 1. The average number of seeds per seed ball by collection date for all trees at Stillwater, OK, and the first two collection dates for all trees at Idabel, OK.

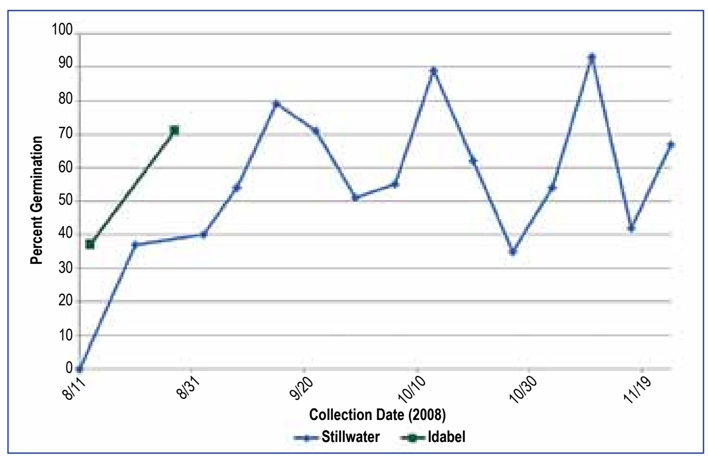

Figure 2. Germination percent by collection date for all trees at Stillwater, OK, and the first two collection dates for all trees at Idabel, OK, to assess maturation.

Figure 3. Photos of a seed ball from Tree 1 (Stillwater, OK) at early maturity, **upper left**, and at full maturity, **upper right**; and a seed ball from Tree 4 (Stillwater, OK) at early maturity, **lower left**, and at full maturity, **lower right**.

Objective 2: The Receptivity Question

The average number of seeds per seed ball across receptivity times (bag removal date) for individual trees varied greatly at each location, ranging from zero to greater than 80 seeds, depending on the tree, collection date, and location (data not shown). On average, however, the Idabel trees had considerably greater seed production than the Stillwater trees (figure 4). As suggested earlier, lower seed set and yield at Stillwater probably reflects a limited pollen cloud on the landscape.

The receptivity seed set count was much lower than the maturation seed set count observed for objective 1. This difference likely reflects the effects of having the seed balls bagged for much of the pollination period. More than 3 days may be required for full seed set, but the simple presence of the bags may have also limited seed set or had other negative effects. Germination data indicate that sweetgum female flowers were most receptive to pollination on the third week of April in Stillwater and approximately 1 week earlier farther south in Idabel (figure 5). As expected, latitude influences flower receptivity timing. Female flowers were receptive almost as soon as they emerged and maximum receptivity was reached in 2 to 3 weeks.

Although the highest numbers of seeds per seed ball at the Idabel location were from a receptivity time in late March, germination percentages were low at that time. High germination percentages did not occur until the second week of April receptivity time. For the Stillwater location, the highest numbers of seeds per seed ball and the highest germination percentages occurred from a receptivity time during the third week of April. This timing difference between the sites is probably attributable to climatic differences due to the 260-mile, north-to-south geographic separation.

Figures 6 and 7 show the physical characteristics over time of seed balls from two of the Stillwater trees. As soon as receptivity was reduced, the stigma showed signs of drying and browning. Most of the trees had green or yellow-green flowers, but some had flowers and fruit with a reddish hue, as seen in figure 7 (lower left). This red coloration persisted until maturity and could disallow the use of color changes to accurately determine maturity. This observation, along with the subtle color changes noted previously (figure 3, upper pictures), further suggests that date may be the most reliable indication of maturity.

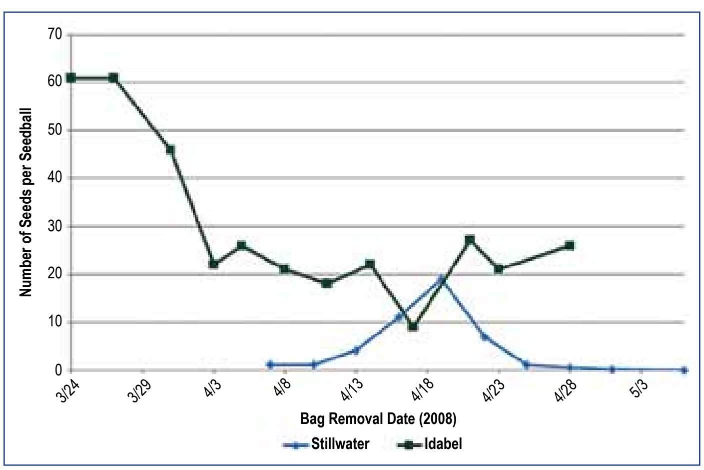

Figure 4. The average number of seeds per seed ball at each receptivity date for all trees at Idabel and Stillwater, OK.

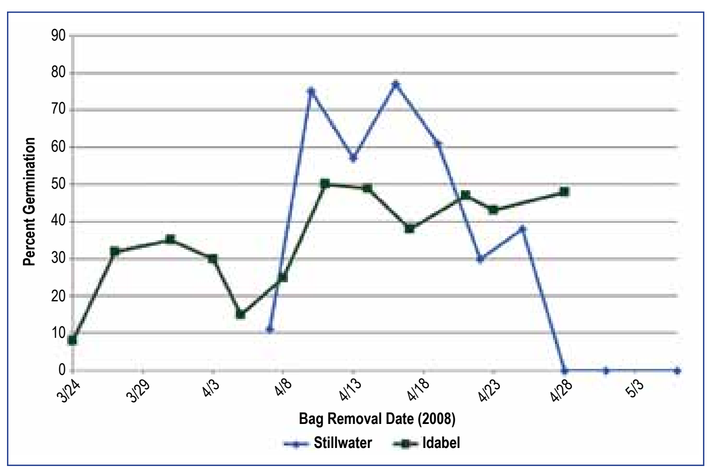

Figure 5. Germination percent by receptivity date for all trees at Idabel and Stillwater, OK.

Figure 6. Photos of Tree 1, Stillwater, OK. **Upper left,** a female flower on the first day of the study; **upper right,** a female flower on day 7; **lower left,** a female flower at peak receptivity; **lower right,** a female flower at the termination of bagging, past receptivity.

Figure 7. Photos of Tree 4, Stillwater, OK. **Upper left,** a female flower on the first day of the study; **upper right,** a female flower on day 7; **lower left,** a female flower at peak receptivity; **lower right,** a female flower at the termination of bagging, past receptivity.

Objective 3: The Selfing Question

Of approximately 40 selfed seed balls from seven trees, only two trees at the Idabel location produced four mature seed balls (three from one bag and one from a second bag). These mature seed balls were the only selfing seed balls harvested from both locations. A total of 25 seeds were extracted from these seed balls and only 8 germinated after stratification. The selfed seed balls may have been pollinated because of self-pollination, may have been pollinated because of contamination resulting from a ripped bag (likely for the single bag with three seed balls), or may have been pollinated before the bags were placed on the female flowers (doubtful). Clearly, these results suggest that sweetgum does not easily self-pollinate.

Conclusions

Seed of sweetgum reaches full maturity by the second week of November in Oklahoma. Seed maturity across the range will no doubt vary by latitude, but a slight yellowing to browning of the seed balls can be indicative of mature seed. Seed balls may be harvested as early as mid September, however, with a minimal loss in germination percent. Since the color changes can be very subtle, we suggest collection based on date and not color.

As expected, female flower pollen receptivity at the southern location occurred earlier. Sweetgum flowers become receptive within 7 days following emergence from the buds and receptivity peaks within 2 to 3 weeks following emergence. If someone's goal is controlled crossing of sweetgum, the flowers should be bagged as soon as they can be recognized following bud break. The bagged flowers should then be pollinated for 14 to 21 days after bagging.

Finally, sweetgum does not easily self-pollinate, if at all.

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Acknowledgments

Pamela K. Tauer was a research specialist at the Department of Horticulture and Landscape Architecture and a graduate student at Oklahoma State University when the work was accomplished. The authors are grateful to Bob Heinemann, Senior Station Superintendent, Kiamichi Forestry Research Station, and his crew for assistance at the Idabel site. The Oklahoma State University Agricultural Experiment Station supported this study.

References

Association of Official Seed Analysts. 1993. Rules for testing seeds. Journal of Seed Technology. 16: 1–113.

Belcher, E.; Vozzo, J. 1979. Radiographic analysis of agricultural and forest tree seeds. Association of Official Seed Analysts Handbook. No. 31. 27 p.

Bonner, F.T. 1974. Liquidambar styraciflua L., sweetgum. In: Schopmeyer C.S., Tech. Coord. Seeds of woody plants in the United States. Agric. Handbk. 450. Washington, DC: U.S. Department of Agriculture, Forest Service: 505–507.

Bonner, F.T. 1987. Collection and care of sweetgum seed. New Forests. 3: 207–214.

Bonner, F.T.; Gammage J.L. 1967. Comparison of germination and viability tests for southern hardwood seed. Tree Planters' Notes. 18(3): 21–23.

Brown, C.K.; Kirkman, L.K. 1990. Trees of Georgia and adjacent States. Portland, OR: Timber Press. 292 p.

Dirr, M.A.; Heuser, C.W., Jr. 2006. The Reference Manual of Woody Plant Propagation: From Seed to Tissue Culture. Cary, NC: Varsity Press. 230–231.

Evans, E.; Blazich, F.A. 1999. Overcoming Seed Dormancy: Trees and Shrubs. North Carolina State University HIL-8704.

Flemion, F. 1948. Reliability of the excised embryo method as a rapid test for determining the germinative capacity of dormant seeds. Contributions of the Boyce Thompson Institute. 15: 229–241.

Fowells, H.A. 1965. Silvics of forest trees of the United States. Agriculture Handbook 271. Washington, DC: U.S. Department of Agriculture, Forest Service. 762 p.

Hartmann, H.; Kester, D. 2002. Plant Propagation: Principles and Practices, Seventh Edition. Englewood Cliffs, NJ: Prentice-Hall. 113–137.

Kormanik, P.P. 1990. Liquidambar styraciflua L., sweetgum. In: Burns, R.M. and Honkala, B.H., tech. cords. Silvics of North America. Volume 2, Hardwoods. Agricultural Handbook. 654. Washington, DC: U.S. Department of Agriculture, Forest Service: 400–405.

Nikolaeva, M.G. 1967. Physiology of deep dormancy in seeds. Komarovskie Chteniya Botanicheskogo Instituta Akademii Nauk SSR [translated by National Technical Information Service. TT 68-50463. 1969. 220 p.].

Schopmeyer, C.S. 1974. Seeds of woody plants in the United States. Agriculture Handbook 450. Washington, DC: U.S. Department of Agriculture, Forest Service. 883 p.

Comparing Planting Tools for Container Longleaf Pine

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Abstract

We examined if compressing the soil to make a planting hole with a custom-built, solid round dibble versus coring the soil with a commercially available tube dibble influenced container-grown longleaf pine seedling development differently. Seventeen months after planting, the planting tool did not significantly affect root collar diameter, shoot or root mass, root-to-shoot ratio, or root system length. Seedlings planted with the solid round dibble, however, had significantly greater numbers of first-order lateral roots and better root system architecture. The light soil texture on the study site was likely an influencing factor in the relative performance between the two planting tools.

Introduction

More than 1 billion conifer seedlings are produced yearly in southern nurseries in the United States for outplanting on forest sites, of which 96 percent are bare root and 4 percent are container stock (McNabb and Enebak 2008). Longleaf pine (*Pinus palustris* Mill.) is the exception, in which only 30 percent of the 33 to 69 million seedlings produced annually is bareroot, and 70 percent is container stock (South and others 2005, McNabb and Enebak 2008). Because of this preference for longleaf pine container stock, research continues across the region to examine the effects of size and type of containers on seedling quality, both in the nursery and after outplanting (e.g., Barnett and McGilvray 2002, South and others 2005, Sword Sayer and others 2009). Naturally regenerated southern pine seedlings develop long lateral roots providing a widespread support system, while the roots from containers seedings are forced downward into the planting hole (Ruehle 1985). Using copper-coated containers can change seedling root morphology by promoting more taproot growth and inhibiting the downward growth of lateral roots, thereby resulting in better distribution of fibrous roots within the container cavity (Barnett and McGilvray 2002). Currently, at least one study is underway to determine if copper-coated containers result in long-term improvement of longleaf pine plantations (Haywood and others 2007).

Planting tools used in container studies vary. South and others (2005) used augers to plant seedlings while Sword Sayer and others (2009) used solid round dibbles or punches. In both cases, however, the research focus was on container type and size; little research has been done to examine planting tools used to plant longleaf container pine seedlings in the West Gulf Coastal Plain. Jones and Alm (1989) and Johnson and others (1998) evaluated planting tools, but their emphasis was on planting errors, seedling survival, and height growth rather than on the direct effects the tools might have on root system development. We hypothesized that the tool used for planting container-grown seedlings affects root system architecture just as much as the container type does. The objective of this study was to compare shoot and root development of seedlings planted with a solid, round dibble, which compresses the soil to make a planting hole versus seedlings planted with a tube dibble, which cores the soil.

Methods

We compared two planting tools (figure 1). The solid-steel, round dibble has a 13.8 cm (5.4 in) long blunt-tipped bit that is 3.5 cm (1.4 in) in diameter at the hilt and the tube dibble has a hollow steel bit 14.7 cm (5.8 in) long with a 2.5 cm (1.0 in) inside diameter and a 3.8 cm (1.5 in) outside diameter at the hilt. The solid round dibble was custom made for planting container seedlings and makes the planting hole by compressing the soil. The tube dibble is sold under several trade names including "Container Seedling Dibble" (Alabama Evergreens, Danville, AL) and makes the planting hole by excavating a soil core.

The longleaf pine seeds came from a Florida source and were supplied by Louisiana Forest Seed Company (Woodworth, LA). Seeds were sown in May 2007 in Copperblock™ Styroblocks (Beaver Plastics model number 112/105, 3.2 cm [1.3 in] diameter with 11.6 cm [4.6 in] depth). Seedlings were grown at the Forest Service, Alexandria Forestry Center (Pineville, LA) using protocols adapted from Barnett and McGilvray (1997, 2000) and described in Sword Sayer and others (2009).

The field site was established on the Palustris Experimental Forest (31° 10' 3"N, 92° 39' 53"W). The site was prescribe-burned in May 2004. The elevation is 72 m (236 ft) above sea level. The growing season (March-November) rainfall for 2008 was 105.4 cm (41.5 in) with average January and July temperatures in 2008 of 9 °C (48 °F) and 28 °C (83 °F), respectively. Previous vegetation was mostly grass, forb, scattered hardwood, and pine brush as described by Duval (1962) and Pearson (1987). The soil is a Malbis fine sandy loam (fine-loamy, siliceous, subactive, thermic Plinthic Paleudults); soil bulk density was determined in August 2009 by collecting 5 soil cores in a systematic pattern (4 corners and center) of the 100 m² (1,076 ft²) study area.

A 10 x 10 m (33 x 33 ft) area was rotary mowed and a fire-exclusion strip was established by tilling around the perimeter. Single-tree plots were established in a completely randomized experimental design. One hundred planting spots were marked with vinyl flags at a 1 x 1 m (3.3 x 3.3 ft) spacing and each was randomly assigned to one of the planting tools so that 50 container seedlings were planted with a solid round dibble and 50 with a tube dibble. Experienced tree planters planted seedlings in November 2007. As standard practice, the grass on the planting spot was scuffed off with a boot and the hole for the seedling was closed with the heel of a boot. After planting, the top of the root plug was either flush or slightly above the soil surface. No additional treatments were applied to the site.

Only one seedling of each planting treatment died during the study period; so, we did not further investigate survival. We measured root collar diameter (RCD) 1 week after planting. The initial average RCDs were 7.2 mm (0.28 in) and 7.3 mm (0.29 in) for the hollow tip and solid tip, respectively, and the differences were not significant (p = 0.65). In April 2009, 17 months after planting, all seedlings were excavated at a 15 cm (5.9 in) radius from the stem, washed, and evaluated. We measured oven-dried shoot and root mass, RCD at harvest, RCD growth, root-to-shoot ratio, and the length of the longest vertical root (tap root and sinker root combined). The number of first-order lateral roots (FOLRs) (primary lateral roots with diameter greater than 1 mm [0.04 in]) egressed from the root plug were counted. We placed each seedling's root system on a diagram divided into quadrants with a solid black central circle that delineated the outside wall of the root plug before outplanting (figure 2). Quadrants with at least one end of an egressed FOLR present were counted for each seedling.

Figure 1. The tool on the left is the solid round dibble with a bit made in the shape of a container cavity, such as those used for growing the seedlings in this study. The tool on the right is a tube dibble that is available commercially from several sources. Both tools are leaning on a Copperblock™ Beaver Plastics Styroblock, model number 112/105, which was the type of container used to grow the longleaf seedlings in this study.

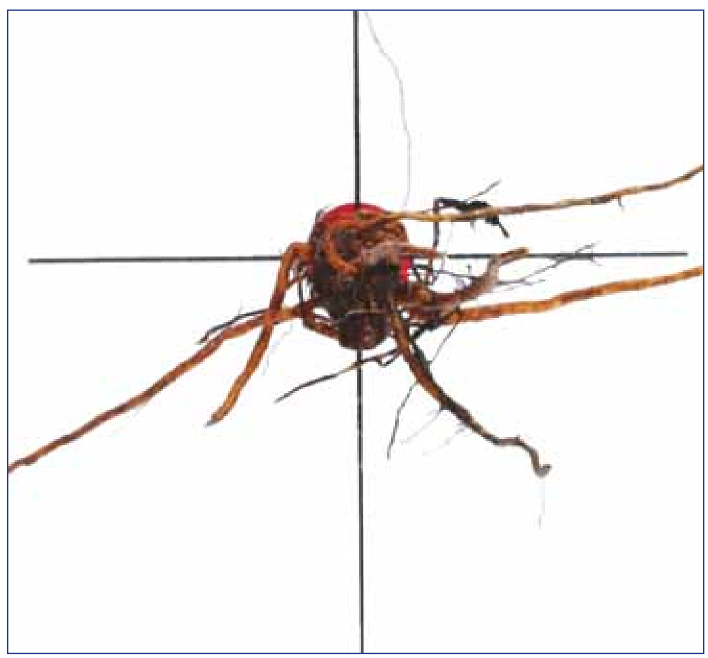

Figure 2. A typical longleaf pine seedling being evaluated for the distribution of egressed roots by quadrant, 17 months after planting. Roots were considered egressed if they were greater than 1 mm (0.04 in) in diameter and exceeded the boundaries of the solid black central circle that delineated the outside wall of the seedling plug before outplanting. A root is considered in the quadrant where it ends.

Differences between the continuous, normally distributed variables were evaluated with a two-tailed t-test at an α level of 0.05 with PROC TTEST (SAS Institute Inc. 1991), and the count variables (egressed FOLRs and quadrants) were compared using a nonparametric Wilcoxon two-sample test with PROC NPAR1WAY (SAS Institute Inc. 1991). The null hypothesis for all variables was that no difference was evident in seedling development between planting tools.

Results and Discussion

We observed no significant differences in seedling development variables between the two planting tools, although seedlings planted with the solid round dibble tended to be slightly larger (table 1). Our results agree with Johnson and others (1998) and Jones and Alm (1989) that no survival or aboveground growth differences are associated with the planting tool. We hypothesized that soil compression from using the solid round dibble would inhibit lateral and vertical root egress from the root plug as compared with seedlings planted into a hole created by removing a soil core with a tube dibble. The number of egressed FOLRs and quadrant counts were significantly greater, however, for seedlings planted by a solid round dibble than by a tube dibble (table 2). This unexpected result may be because the solid round dibble size more closely matched that of the planted plug or that the compressed soil expanded after planting and resulted in a tighter plug-to-soil interface favoring FOLR egression, or that compression was short-term and inconsequential in this soil type.

Soil texture is likely an influencing factor as well. Barnett (1978) found that loblolly pine seedlings survived better in a heavy silt loam when planting holes were cored rather than dibbled. Similarly, survival and height growth of lodgepole pine (*Pinus contorta* Dougl. Ex Loud.) in a compacted clay loam was best when a soil core was removed for planting (Bohning 1981). In both studies, seedling survival in light-textured soils (bulk density < 1.6 g/cm^3 [100 lb/ft^3]) was as good or better in dibbled holes (Barnett and Brissette 1986). Barnett (1978) suggested that using the solid dibble compacts the soil and could reduce the ability of the root system to penetrate the sides of the hole, but provides no reason for the better performance of the dibble in light-textured soils. The soil bulk density in our study plots was 1.48 g/cm^3 (92 lb/ft^3) suggesting it was too light-textured for negative compaction effects to occur by the dibble.

Conclusions

In Sword Sayer and others (2009), the development of FOLRs and root system architecture were considered important in predicting seedling access to surface soil resources, growth, and the future stability of saplings and trees in high, sustained winds. Although the tool differences were slight, better root system development may result after outplanting when a solid round dibble is used to plant copper-coated container seedlings in light-textured soils. These results may or may not apply to other container types or soils.

Table 1. Mean growth variables for longleaf pine seedlings planted with a tube or solid round dibble and the t-test statistics.

Variable	Tube dibble	Solid round dibble	T-statistic	Probability > |t|
Shoot mass (g/oz)	13.6/0.48	14.2/0.50	– 0.71	0.4805
Root mass (g/oz)	12.8/0.45	13.1/0.46	– 0.33	0.7402
RCD (mm/in)	18.8/0.74	19.3/0.76	– 1.02	0.3120
RCD growth (mm/in)	11.6/0.46	12.0/0.47	– 0.81	0.4177
Root/shoot ratio	0.95	0.96	– 0.33	0.7388
Length of the longest root (cm/in)	30.2/11.9	30.4/12.0	– 0.15	0.8811

RCD = root collar diameter.

Table 2. Mean root system architecture variables for longleaf pine seedlings planted with a tube or solid round dibble and the Z-test statistics from the nonparametric Wilcoxon test.

Variable	Tube dibble	Solid round dibble	T-statistic	Probability > |Z|
FOLR count	3.2	4.4	– 2.491	0.0127
Number of quadrants[a]	1.6	2.1	– 2.392	0.0168

FOLR = first-order lateral roots.

[a] Number of quadrants into which at least one FOLR root ended that had egressed from the root plug.

References

Barnett, J. P. 1978. Advances in container production of planting stock. In: Hollis, C. A.; Squillace, A. E., eds. Proceedings Fifth North American Forest Biology Workshop: Theme—Physiological and genetical implications of forestry on difficult sites. Asheville, North Carolina, U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 167–175.

Barnett, J.P.; Brissette, J.C. 1986. Producing southern pine seedlings in containers. Gen. Tech. Rep. SO-GTR-59. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 71 p.

Barnett, J.P.; McGilvray, J.M. 1997. Practical guidelines for producing longleaf pine seedlings in containers. Gen. Tech. Rep. SRS-GTR-14, Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 28 p.

Barnett, J.P.; McGilvray, J.M. 2000. Growing longleaf pine seedlings in containers. Native Plants Journal. 1(1): 54–58.

Barnett, J.P.; McGilvray, J.M. 2002. Copper-treated containers influence root development of longleaf pine seedlings. Proceedings of workshops on growing longleaf pine in containers—1999 and 2001. Gen. Tech. Rep. SRS-GTR-56. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 24–26.

Bohning, R. 1981. Core dibble reduces impact of soil compaction on seedling growth. Forestry Report No. 24. Edmonton, Alberta, Canada: Canadian Forestry Service, Northern Forest Research Center: 15.

Duval, V.I. 1962. Burning and grazing increase herbage on slender bluestem range. Journal of Range Management. 15(1): 14–16.

Haywood, J.D.; Sword Sayer, M.A.; and Sung, S.S. 2007. Study plan and establishment report: Long-term comparison of root and stem growth of outplanted longleaf pines grown in six kinds of container. Unpublished report. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 15 p.

Johnson, R.; Pancake, D.; Hainds, M.; and Gjerstad, D. 1998. The effects of planting tool on planting productivity and survival of longleaf pine bare-root seedlings. In: Waldrop, T.A., ed. Proceedings of the ninth biennial southern silvicultural research conference; 1997 February 25-27; Clemson, SC. Gen. Tech. Rep. SRS-GTR-20. Asheville, NC: U.S. Department of Agriculture Forest Service, Southern Research Station: 99–102.

Jones, B.; Alm, A.A. 1989. Comparison of planting tools for containerized seedlings: two-year results. Tree Planters' Notes. 40(2): 22–24.

McNabb, K; Enebak, S. 2008. Forest tree seedling production in the southern United States: the 2005–2006 planting season. Tree Planters' Notes. 53(1): 47–56.

Pearson, H.A.; Grelen, H.E.; Parresol, B.R.; Wright, V.L. 1987. Detailed vegetative description of the longleaf-slash pine type, Vernon District, Kisatchie National Forest, Louisiana. In: Pearson, H.A.; Smeins, F.E.; Thill, R.E., compilers. Ecological, physical, and socioeconomic relationships within southern National Forests: Proceedings of the southern evaluation project workshop; 1987 May 26-27; Long Beach, MS. Gen. Tech. Rep. SO-68. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 107–115.

Ruehle, J.L. 1985. The effect of cupric carbonate on root morphology of containerized mycorrhizal pine seedlings. Canadian Journal of Forest Research. 15(3): 586–592.

SAS Institute Inc. 1991. SAS/STAT User's Guide, Version 6, Fourth Edition, Volume 2. SAS Institute Inc., Cary, NC. 846 p.

South, D.B.; Harris, S.W.; Barnett, J.P.; Hainds, M.J.; and Gjerstad, D.H. 2005. Effect of container type and seedling size on survival and early height growth of *Pinus palustris* seedlings in Alabama, U.S.A. Forest Ecology and Management. 204(2–3): 385–398.

Sword Sayer, M.A.; Haywood, J.D.; and Sung, S.S. 2009. Cavity size and copper root pruning affect production and establishment of container-grown longleaf pine seedlings. Forest Science. 55(5): 377–390.

RNGR: A National Resource for Reforestation, Restoration, and Nursery Professionals

Diane L. Haase, Jeremiah R. Pinto, R. Kasten Dumroese, George Hernandez, Bob Karrfalt, and Ron Overton

Members of the National RNGR Team (see table 1 for titles and locations)

Abstract

The Forest Service developed the national Reforestation, Nurseries, and Genetics Resources (RNGR) program to provide expert support to State, industrial, and private forest and conservation nurseries throughout the country. The RNGR program includes technical assistance to nurseries, research projects (to address seedling and field issues), and Internet sites. RNGR personnel publish periodicals, handbooks, and scientific articles and host annual nursery conferences and workshops. The National Seed Laboratory (NSL) and a Tribal Nursery Emphasis are also integral components of RNGR's mission.

The RNGR Program

The success of reforestation and restoration projects can greatly hinge on the use of high-quality and appropriate plant materials produced in nurseries. When implemented successfully, these projects contribute to air and water quality, wildlife habitat, biodiversity and ecosystem sustainability, timber production, healthy forests, and reduced soil erosion. Collectively, about 1,200 nurseries nationwide currently satisfy the need for plant materials used in restoration, reforestation, and conservation efforts. Although demand for commercial timber species declined during the past decade, demand for other native plant species, each having its own cultural and site requirements, has risen dramatically. Consequently, requests for information about how to propagate, store, ship, and plant specific native plant species have grown faster than the information is being developed. In addition, information associated with the use of native plants to address climate change, invasive species, and ecosystem services is lacking. Concurrently, relevant expertise and research resources within Federal and State agencies, universities, and other organizations have declined to levels outpaced by the need. To address this disparate trend in native plant knowledge and to continue supporting information needs for conventional forest species, a small team of specialists within the USDA Forest Service provides regional and national coordination of technical assistance to nursery, reforestation, restoration, and seed professionals.

The Forest Service is responsible for assisting States with producing, distributing, and planting seedlings on private land. In 2001, the agency created the RNGR Program. A national group of technical specialists located across the country is referred to as the "RiNGeR Team" (table 1). The RNGR Team assists Federal, State, territorial, tribal, and private nurseries by providing technical assistance aimed toward production of adequate supplies of reasonably priced, high-quality, genetically well-adapted seedlings for reforestation, conservation, and restoration. The team provides technical expertise on cost-effective propagation and planting methods that improve seedling survival and growth. The Forest Service NSL is also a key component of the RNGR Program, particularly with emerging needs for germplasm conservation. Geographically dispersed RNGR Team members are attuned to regional needs, but act nationally to bring significantly more expertise to solve localized problems through information sharing.

Table 1. The national RNGR Team and its affiliates.

The team		
R. Kasten Dumroese	Research Plant Physiologist and Editor, *Native Plants Journal*	Moscow, ID
Diane L. Haase	Western Nursery Specialist and Editor, *Tree Planters' Notes*	Portland, OR
George Hernandez	Southern Nursery Specialist	Atlanta, GA
Robert Karrfalt	National Seed Laboratory Director	Dry Branch, GA
Ronald Overton	Northeastern Nursery Specialist	West Lafayette, IN
Jeremiah R. Pinto	Tribal Nursery Coordinator and Research Plant Physiologist	Moscow, ID
RNGR affiliates		
Matt Howell	Information Technology Manager	Athens, GA
Tom Landis	Nursery Specialist Emeritus and Editor, *Forest Nursery Notes*	Medford, OR

The RNGR Program has several components, including Technical Assistance, a Research Program, a Tribal Nursery Emphasis, the NSL, and Collaborative Agreements and Cooperative Efforts. Each component is described below.

Technical Assistance

The team provides expert support to forest and conservation nurseries throughout the country. This support entails advising nursery managers and other plant professionals on a variety of issues and opportunities pertaining to seedling production, native plant restoration, and forest regeneration. The team assists nurseries with problem solving and provides guidance in developing strategies to address seedling quality issues. Through reports, publications, presentations, conferences, workshops, and onsite visits, RNGR personnel provide key information to aid in the understanding and implementation of effective technology for bareroot and container nursery operations.

Periodicals—Members of the RNGR Team are directly responsible for producing the *Native Plants Journal*, *Tree Planters' Notes,* and *Forest Nursery Notes*. Each of these publications delivers information and research results to the worldwide nursery, restoration, and reforestation communities. These periodicals feature easy-to-understand, hands-on information that can be readily applied in the field.

USDA Agriculture Handbooks—These publications summarize current knowledge on specific subjects, providing a source of information and reference for field professionals. *The Container Tree Nursery Manual* (seven volumes) (Landis and others 1989-2010, figure 1) is the standard for the industry and is the most downloaded publication from the RNGR Internet site (see next section). The final volume, *Seedling Processing, Storage, and Outplanting,* was published in 2010 (Landis and others 2010). Other handbooks published by RNGR are *The Woody Plant Seed Manual* (Bonner and Karrfalt 2008) and the two-volume *Nursery Manual for Native Plants: A Guide for Tribal Nurseries* (Dumroese and others 2009c). Two additional handbooks being written are the *Tropical Nursery Manual* and the *Hardwood Nursery Manual*. Full citations for recent RNGR publications are listed at the end of this article.

Internet Sites—The RNGR site (http://rngr.net) has the largest online collection of articles on producing native plants for reforestation, conservation, or restoration (approximately 7,000 articles and growing). All articles are searchable and are free to download. The publication database includes all issues of *Forest Nursery Notes* (1993–present), *Tree Planters' Notes* (1950–present), and the National Nursery Proceedings (1949–present) and many other articles. The RNGR site is used extensively by nursery and regeneration professionals around the world. During the past 2 years, the site had 100,782 visits and 92,251 content downloads by visitors from 199 countries—averaging one visit and one download every 10 to 12 minutes. In addition, the RNGR site contains a national nursery and seed directory, a calendar of events, a list of relevant links, and information about the RNGR Program and personnel (figure 2). RNGR personnel also created the Native Plants Network site (http://www.nativeplantnetwork.org). This one-of-a-kind searchable database contains approximately 3,000 propagation protocols for native plants. New protocols can be added by anyone willing to upload and share his or her techniques.

Conferences—RNGR assists with organization and management of the western, southern, and northeastern regional nursery conferences and the annual Intertribal Nursery Council meeting. These events provide the venue for sharing technical information, networking, and discussing emerging issues that

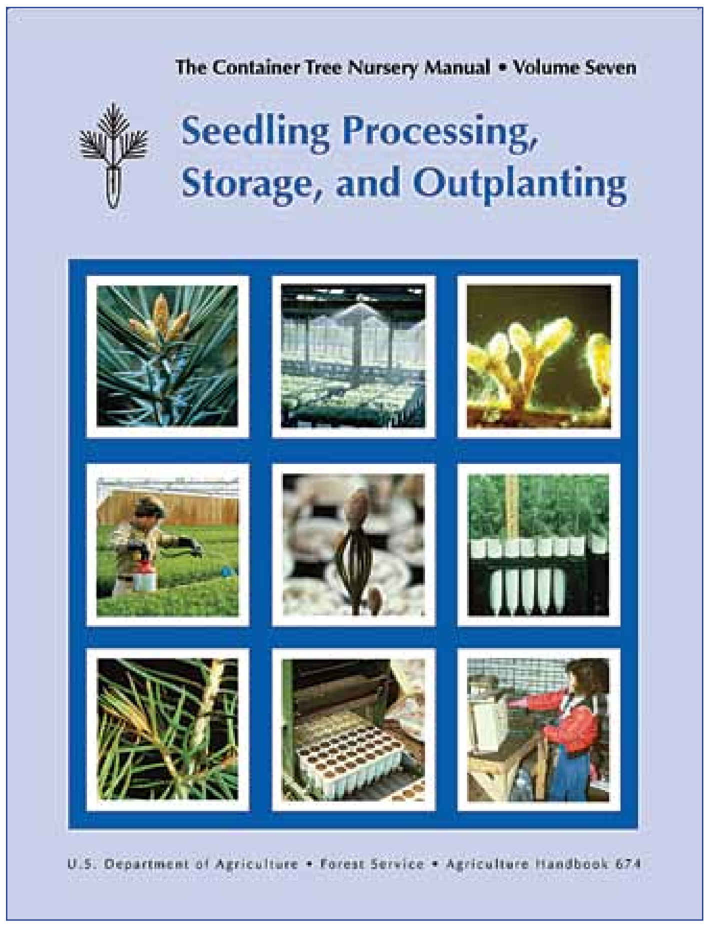

Figure 1. *The Container Tree Nursery Manual* (seven volumes) serves as the industry standard for production of container seedlings for reforestation and restoration.

confront nursery managers. Papers presented at these conferences are published by RNGR in the annual *National Nursery Proceedings* (available at the RNGR Web site).

Training—RNGR has organized or conducted training in tropical nursery management, seed collection, seed conditioning, native plant propagation, tree planting, longleaf ecosystem restoration, and hardwood nursery management (figure 3). In addition, RNGR Team members regularly give presentations at various forestry and conservation events.

Figure 2. The popular RNGR Web site has more than 7,000 downloadable articles and a national nursery directory, calendar of events, description of the RNGR program, and other resources.

Figure 3. Members of the RNGR Team regularly organize or participate in conferences and workshops to provide technical support to nurseries.

Research Program

The RNGR Team facilitates, coordinates, and conducts administrative studies and research projects among a variety of partners within government agencies, universities, and nongovernmental organizations. This work assesses and responds to specific nursery and field questions and problems, and the results are shared with managers through technology transfer presentations and publications and with peer scientists through refereed science articles (figure 4). Recent and current studies include developing protocols for assessing hardwood seedling quality and cold hardiness in the Central, Eastern, and Southern United States (Apostol and others 2007, 2009; Haase 2008; Islam and others 2008b; Jacobs and others 2008); examining acorn viability (Goodman and others 2005); identifying stock types and site preparation methods for restoration of native hardwoods in Hawaii (Dumroese and others 2009b, 2011); using fall fertilization to improve seedling growth and reduce nutrient leaching in nurseries in the Midwest (Islam and others 2008a, 2009); developing subirrigation methods for container seedlings to reduce water use and potential pollution nationwide (Dumroese and others 2006, 2007, 2011; Pinto and others 2008; Davis and others 2008); enhancing techniques for growing longleaf pine seedlings in the Southern United States (Dumroese and others 2005, 2009a; Barnett and Dumroese 2006; Jackson and others 2010); investigating the use of biochar as a media substrate in containers; and tracking isotope signatures and their relationship to seedling physiology during production.

Tribal Nursery Emphasis

American Indian tribes are working hard to preserve their traditional ecological knowledge and to develop and enhance production of native plants for spiritual, medicinal, cultural, land restoration, reforestation, and educational uses. Since 2001, the RNGR Team has emphasized outreach to tribes to foster long-term collaborations focusing on native plants, nurseries, and educational activities. In 2003, a *Tribal Nursery Needs Assessment* (Luna and others 2003) was published; it was the first survey of American Indian native plant needs and the first national directory of tribal nurseries.

The RNGR Tribal Nursery Emphasis currently has three components: (1) ongoing technical assistance to tribes about collection, propagation, and deployment of native plants; (2) organization of the Intertribal Nursery Council, an annual forum for tribal members to gather and discuss important topics relevant to native plants (figure 5); and (3) production of a comprehensive guide detailing nursery development and

Figure 4. Research projects are designed to solve problems, answer questions, and generate new technical information for field and nursery personnel to apply. **On left:** research focuses on a variety of species, such as blue spruce, big sage, and longleaf pine. **On right:** various measurements are conducted to evaluate plant quality in response to treatments. This study examined the effects of different irrigation and fertilization levels on photosynthesis.

native plant propagation as it relates to tribes. The guide, *Nursery Manual for Native Plants: A Guide for Tribal Nurseries, Volume 1, Nursery Management* (Dumroese and others 2009c, figure 6), includes information on nursery start-up, development and management, growing plants, and problem solving. Volume 2, Plant Propagation Protocols, is in preparation and contains nearly 300 protocols of plants identified in the *Tribal Nursery Needs Assessment*.

Figure 5. The Intertribal Nursery Council meets annually to promote networking among tribal members and to discuss technology and programs for plant production.

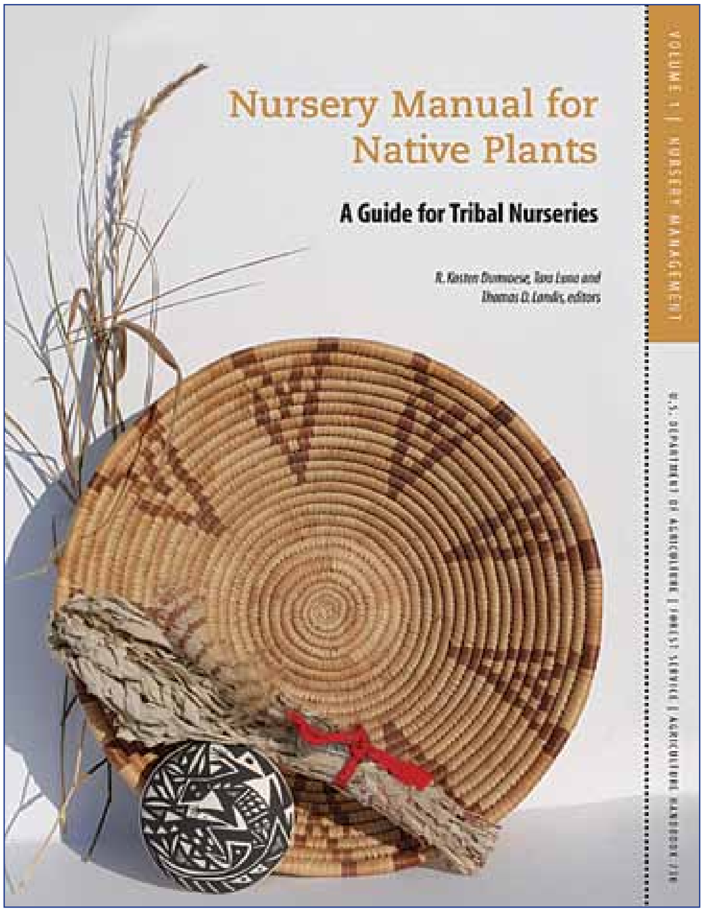

Figure 6. The first volume of the *Nursery Manual for Native Plants: A Guide for Tribal Nurseries* focuses on nursery management and covers all aspects of managing a native plant nursery, from initial planning through crop production to establishing trials and improving nursery productivity into the future.

To date, the program has assisted nearly 80 tribes across the United States and Canada and has worked one on one with more than 500 professionals within those tribes. This assistance has included conducting various nursery training workshops, organizing information-sharing meetings, and technical assistance. In addition, RNGR helped construct a Cultural Plant Propagation Center, a greenhouse that was developed in partnership with the Moencopi School near Tuba City, AZ, to enhance conservation education, promote restoration, and provide opportunities for Hopi and Navajo elders to interact with children and share traditional ecological knowledge. The Tribal Nursery Emphasis program will continue to foster technology transfer through the annual Intertribal Nursery Council meeting, identify funding opportunities and seek innovative partnerships to enable tribes to develop their own nurseries, provide organizational structure and expertise for Forest Service support of tribal nursery and ecosystem efforts, and continue to build and maintain collaborative and trusting government-to-government relationships.

National Seed Laboratory

Sufficient quantities of seeds are needed to restore and sustain native plant communities that are increasingly affected by invasive species, pest infestations, wildfire, overuse by humans, inherent biology, and climate change. Supplying these seeds is complex as each species has its own unique seed production and germination protocols. As well, it has become increasingly evident that successful seed production and storage is important for preserving the genetic integrity of endangered species and other plants being lost in large numbers in the wild. The National Seed Laboratory (NSL) serves as the primary national strategic resource for forest ecosystem seed science and technology; it directly addresses the complex challenges associated with the use of seed for conservation and restoration. Located in Macon, GA, the NSL originated in the 1950s to support southern pine restoration work but has undergone several evolutions since then, thereby diversifying its purpose. The latest change occurred in 2005, when the Chief of the Forest Service expanded the NSL's mission to include all native plants, with an emphasis on gene conservation through long-term seed storage.

The NSL is diverse in its seed service offerings. It develops protocols for seed cleaning, germination, and storage of a variety of native forest plant seeds, ranging from commercial timber species to herbaceous understory plants. It provides onsite seed storage for many conservation species and in security backup vaults maintained in Fort Collins, CO. The NSL provides training materials, workshops, and customized individual training programs to U.S. and international seed workers. It also collaborates with research and production facilities worldwide and participates in several national and international conferences every year. NSL staff members are authors and co-editors of *The Woody Plant Seed Manual* (Bonner and Karrfalt 2008, figure 7).

The NSL performs seed tests for private industry, State governments, and Federal agencies. Results are used in forest and conservation nurseries to make efficient use of seeds, to evaluate seed quality in processing plants, and as the basis for seed price determination. The NSL is the only U.S. facility accredited by the International Seed Testing Association (ISTA) to test forest seeds.

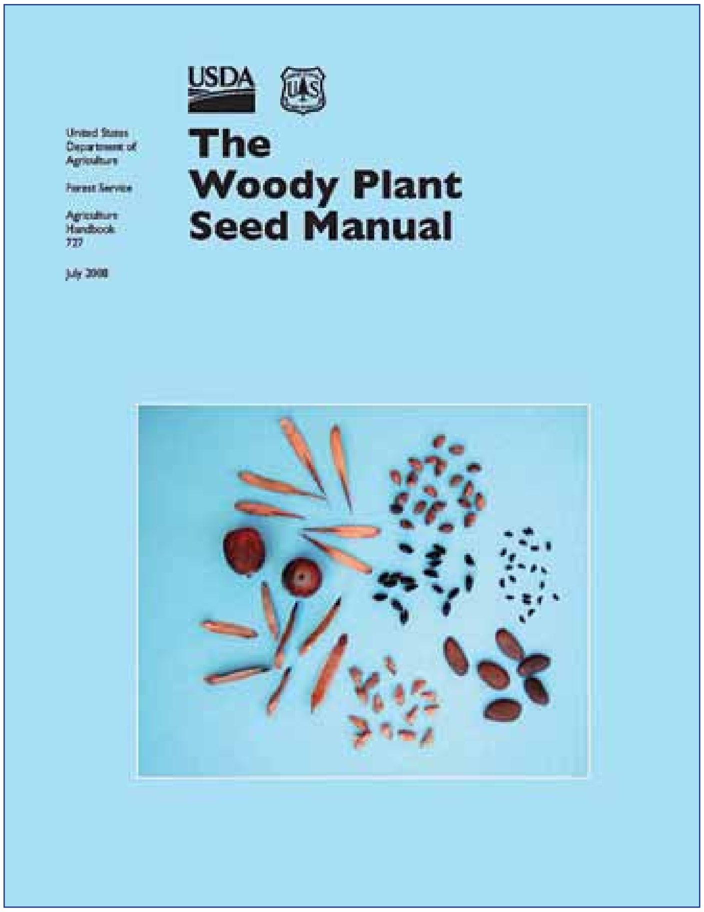

Figure 7. *The Woody Plant Seed Manual* includes seven chapters on general principles such as seed biology, harvesting, storage, testing, and nursery practices and detailed information on 236 genera of native and introduced woody plants.

Collaborative Agreements and Cooperative Efforts

To leverage scarce resources, RNGR partners with universities, Federal agencies, and State agencies to provide training, technical assistance, and research to nursery and reforestation programs. In addition, RNGR works with International Forestry, the Institute for Pacific Island Forestry, and the International Institute for Tropical Forestry to provide assistance to programs in the Caribbean and Pacific. RNGR collaborates with the USDA Foreign Agricultural Service (FAS), the U.S. Agency for International Development, U.S. Fish and Wildlife Service, and the Food and Agriculture Organization of the United Nations to provide nursery and reforestation assistance internationally (e.g., RNGR provided FAS with a nursery manual and training tools for use in Afghanistan). RNGR has collaborated to translate (and print) the *Container Tree Nursery Manual* into Spanish and Chinese languages.

Clearly, the national RNGR Program provides significant support to forest and conservation nurseries nationally and internationally and is continually striving to meet the growing needs of these nurseries as well. To learn more about RNGR, its programs, its members or affiliates, or to request assistance, please visit the RNGR Web site (http://rngr.net).

References

Apostol, K.G.; Jacobs D.F.; Wilson, B.C.; Salifu, K.F.; Dumroese, R.K. 2007. Growth, gas exchange, and root respiration in northern red oak (*Quercus rubra*) seedlings exposed to low root temperatures. Forest Ecology and Management. 253: 89–96.

Apostol, K.G.; Jacobs D.F.; Salifu, K.F.; Dumroese, R.K. 2009. Root desiccation and drought stress responses of bareroot *Quercus rubra* seedlings treated with a hydrophilic polymer root dip. Plant and Soil. 315: 229–240.

Barnett, J.P.; Dumroese, R.K. 2006. Separating live from dead longleaf pine seeds: good and bad news. In: Connor, K., ed. Proceedings of the 13th Biennial Southern Silvicultural Research Conference. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. Gen. Tech. Rep. SRS-GTR-92: 81–84.

Bonner, F.T.; Karrfalt, R.P., eds. 2008. The Woody Plant Seed Manual. Agric. Handbook No. 727. Washington, DC: U.S. Department of Agriculture, Forest Service. 1,223 p.

Davis, A.S.; Jacobs, D.F., Overton, R.P.; Dumroese, R.K. 2008. Influence of irrigation method and container type on growth of *Quercus rubra* seedlings and media electrical conductivity. Native Plants Journal. 9: 4–13.

Dumroese, R.K.; Parkhurst, J.; Barnett, J.P. 2005. Controlled release fertilizer improves quality of container longleaf pine seedlings. In: Dumroese, R.K.; Riley, L.E.; Landis, T.D., technical coordinators. National proceedings, forest and conservation nursery associations—2004. Proceedings RMRS-P-35. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 3–8.

Dumroese, R.K.; Pinto, J.R.; Jacobs, D.F.; Davis, A.S.; Horiuchi, B. 2006. Subirrigation reduces water use, nitrogen loss, and moss growth in a container nursery. Native Plants Journal. 7: 253–261.

Dumroese, R.K.; Jacobs, D.F.; Davis, A.S.; Pinto, J.R.; Landis, T.D. 2007. An introduction to subirrigation in forest and conservation nurseries and some preliminary results of demonstrations. In: Riley, L.E.; Dumroese, R.K.; Landis, T.D., technical coordinators. National proceedings, forest and conservation nursery associations—2006. Proceedings RMRS-P-50. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 20–26.

Dumroese, R.K.; Barnett, J.P.; Jackson, D.P.; Hainds, M.J. 2009a. 2008 interim guidelines for growing longleaf pine seedlings in container nurseries. In: Riley, L.E.; Dumroese, R.K., technical coordinators. National proceedings, forest and conservation nursery associations—2008. Proceedings RMRS-P-58, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 101–107.

Dumroese, R.K.; Jacobs, D.F.; Davis, A.S. 2009b. Inoculating *Acacia koa* with Bradyrhizobium and applying fertilizer in the nursery: effects on nodule formation and seedling growth. HortScience. 44: 443–446.

Dumroese, R.K.; Luna, T.; Landis, T.D., editors. 2009. Nursery manual for native plants: A guide for tribal nurseries—Volume 1: Nursery management. Agriculture Handbook 730. Washington, DC: U.S. Department of Agriculture, Forest Service. 302 p.

Dumroese, R.K.; Davis, A.S.; Jacobs, D.F. 2011. Nursery response of *Acacia koa* seedlings to container size, irrigation method, and fertilization rate. Journal of Plant Nutrition 34(6): in press.

Goodman, R.C.; Jacobs, D.F.; Karrfalt, R.P. 2005. Evaluating desiccation sensitivity of *Quercus rubra* acorns using X-ray image analysis. Canadian Journal of Forest Research. 35: 2823–2831.

Haase, D.L. 2008. Understanding forest seedling quality: measurements and interpretation. Tree Planters' Notes. 52(2): 24–30.

Islam, M.A.; Apostol, K.G.; Jacobs, D.F.; Dumroese, R.K. 2008a. Effects of fall fertilization on morphology and cold hardiness of red pine (*Pinus resinosa* Ait.) seedlings. In: Dumroese, R.K.; Riley, L.E., technical coordinators. National proceedings, forest and conservation nursery associations—2007. Proceedings RMRS-P-57. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72–78.

Islam, M.A.; Jacobs, D.F.; Apostol, K.G.; Dumroese, R.K. 2008b. Transient physiological responses of planting Douglas-fir seedlings with frozen or thawed root plugs under cool-moist and warm-dry conditions. Canadian Journal of Forest Research. 38: 1517–1525.

Islam, M.A.; Apostol, K.G.; Jacobs, D.F.; Dumroese, R.K. 2009. Fall fertilization of *Pinus resinosa* seedlings: nutrient uptake, cold hardiness, and morphological development. Annals of Forest Science. 66(2009): 704. 9 p.

Jackson, D.P.; Dumroese, R.K.; Barnett, J.P.; Patterson, W.B. 2010. Effects of liquid fertilizer application on the morphological and outplanting success of container longleaf pine. In: Stanturf, J.A., editor. Proceedings of the 14th Biennial Southern Silvicultural Research Conference. e-Gen. Tech. Rep. SRS-GTR-121. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 229–234.

Jacobs, D.F.; Davis, A.S.; Wilson, B.; Dumroese, R.K.; Goodman, R.C.; Salifu, K.F. 2008. Short-day treatment alters Douglas-fir seedling dehardening and transplant root proliferation at varying rhizosphere temperatures. Canadian Journal of Forest Research. 38: 1526–1535.

Landis, T.D.; Dumroese, R.K.; Haase, D.L. 2010. The Container Tree Nursery Manual: Volume 7, Seedling processing, storage, and outplanting. Agric. Handbook No. 674. Washington, DC: U.S. Department of Agriculture, Forest Service. 199 p.

Luna, T.; Landis, T.D.; Pinto, J., compilers. 2003. Intertribal Nursery Council: Tribal Nursery Needs Assessment. Asheville, NC: Southern Research Station and State and Private Forestry: Reforestation, Nurseries, and Genetics Resources. 85 p.

Pinto, J.R.; Chandler, R.A.; Dumroese, R.K. 2008. Growth, nitrogen use efficiency, and leachate comparison of subirrigated and overhead irrigated pale purple coneflower seedlings. Hortscience. 43(3): 897–901.

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