Choose Your Planting Stock Carefully

MISSISSIPPI STATE UNIVERSITY EXTENSION

Genetic research efforts, especially in pine, have made a variety of improved planting stock available to forest landowners and professional foresters. These new options can greatly affect forest products and the length of rotation. The combination of seedling genetics, inherent soil characteristics, seedling quality, and management strategies can greatly increase economic return. However, many forest landowners rarely consider the genetic quality of the seedlings they will be planting.

Most landowners and professional foresters consider open-pollinated third-generation pine seedlings to be the highest genetic quality pine stock available. But newly developed pine planting stock is also being made available to landowners. These include highly tested advanced-generation seedlings, full-sib seedlings, and clonal stock.

Unlike pine, the ability to manipulate genetic quality of most hardwood planting stock is severely limited. Most genetic advances have been made with fast-growth hardwoods because they are easy to reproduce vegetatively and they are compatible with plantation culture. While these hardwoods grow extremely rapidly at early ages, this growth rate is only attained on sites with high fertility and good moisture availability.

Genetic improvement of quality hardwood sawtimber species, such as cherrybark oak (*Quercus pagoda* Raf.), has been lacking because of its long rotation length, limited site adaptability, and inability to regenerate through vegetative propagation. For these hardwoods, genetic improvement has followed the seed orchard scenario developed in pine.

Private forest landowners should look into availability of improved seed or seedlings. If you can't find improved stock, ask about the source of available seedlings and make sure it matches the geographic area of the planting site.

Historical Seed Orchard Information

In Mississippi and throughout the South, the majority of pine acreage is regenerated to loblolly pine (*Pinus taeda* L.). In the 1970s, first-generation loblolly pine seed orchards began producing improved seed for plantation establishment. These first-generation orchards were constructed from mature selections taken from natural stands and grafted into an orchard setting.

The loblolly pine literature frequently reported estimated first-generation genetic gains of 8 to 10 percent over non-improved seedlings. Most first-generation orchards were composed of a large number of selected parents with unproven genetic quality. Extensive progeny testing of these first-generation seed orchards allowed elimination of those poorer performing parents.

Removing poorer performing parents based on their progeny performance is called *roguing*. The resulting rogued orchard is referred to as a 1.5-generation seed orchard. The significance of a rogued orchard is that only the best parents remain, which should theoretically increase genetic gains.

The majority of seedlings planted in the southeastern United States are open-pollinated seedlings from second-generation seed orchards. Selections that comprise second-generation seed orchards are the result of specifically designed mating schemes within the breeding population followed by extensive progeny testing and selection of the best performers. But similar to first-generation orchard roguing, progeny testing of the second-generation orchard can eliminate below-average parents.

Advanced-generation orchards are also being established, with the best genetic selections currently available based on performance regardless of generation. Estimated genetic gains from second-generation orchards range from 13 to 21 percent over improved stock, while gains from rogued second-generation (i.e., 2.5 orchard) and advanced-generation orchards have been estimated to be 26 to 35 percent over unimproved stock.

Use of Improved Planting Stock

Development of improved planting stock for the southeast U.S. was primarily driven by tree improvement cooperatives located at North Carolina State University, the University of Florida, and the Texas Forest Service. Various state forestry agencies and industrial companies were members of one or more of these cooperatives. Some of the larger forestry companies, while belonging to a cooperative, also had their own tree improvement programs.

Over the last two decades, the forestry industry has experienced much consolidation, with the majority of remaining companies selling their land base. To counter this, many companies signed fiber contracts with purchasing groups to ensure a flow of fiber to their mills. Most companies emphasized growth of their plantations, with limited regard for form or quality.

In the late 1980s, the forestry industry began moving away from seed orchard mixes to single-family plantings as they focused on increasing yields by growing specific families on selected sites. For these single-family plantings, seed are collected from a single parent from a specified orchard. All seedlings developed from this seed share the same mother, but the pollen parents (i.e., fathers) are unknown.

To take advantage of single-family genetic uniformity, that family's performance must be tracked through time on a specific site. This led many forestry companies in the Southeast to invest in intensive land classification to complement their genetics program. This provided information that could be used to determine feasibility of silvicultural techniques and lower growing costs. While time-consuming, the process provided a wealth of information on soil type, structure, nutrients, moisture availability, vegetative management, and geologic information.

A land classification system, used in combination with extensive genetic testing, led to a mosaic of single-family plantings, which soon became the norm for many forestry companies across the South. The reduction in genetic diversity within a single-family planting has been questioned both within and outside of the forestry community. However, no problems associated with limiting genetic variation in plantations by planting single families has been noted. As knowledge about advanced-generation parents increased, many companies looked for ways to capture additional genetic gains.

Before 2008, Mississippi forest landowners could obtain improved loblolly pine seedlings from the Mississippi Forestry Commission (MFC). Advanced-generation seed produced by the MFC was collected from orchards located in south Mississippi. These orchards were designed for two planting zones, known as North and South Loblolly Zones.

The South Zone extended from the coast to the northern county lines of Kemper, Leake, Madison, Neshoba, and Yazoo Counties. The orchard used for the North Zone contained selections that originated from Noxubee County south to Jones County. The South Zone orchard consisted of selections from Livingston Parish, Louisiana, and Amite, Wilkinson, and Pike Counties in Mississippi.

In both zones, MFC seedling guidelines recommended using a mixture of seed, known as a seed orchard mix. The MFC orchard mix typically consisted of 15–20 selections and was designed to provide a broad genetic base buffering against various environmental effects and site quality differences. These guidelines were a conservative approach taken to provide a base of genetic material capable of tolerating variable site quality and management differences among landowners.

Newly Improved Planting Stock Types

As information was analyzed regarding which second-generation parent companies wanted to deploy, new advanced-generation material was being bred. Resulting progeny was included in tests.

Performance of these full-sib progeny from the advanced-generation testing phase initiated interest in use of full-sib seedlings as commercial planting stock. Full-sib progeny are the result of mating excellent-performing male and female parents through a control-pollination process.

The problem with using this seed was insufficient quantity to support a large-scale regeneration program. Research efforts overcame this obstacle using a process known as mass-control pollination (MCP) or supplemental-mass pollination (SMP). MCP seedlings have greater uniformity in growth, form, and disease resistance.

Currently, MCP or SMP seedlings are available through some nurseries at approximately $130 to $180 per thousand seedlings, which is two to three times the cost of typical open-pollinated seedlings. To take advantage of MCP seedlings, you need information at least on the parental performance in a specific area. It is even better to have information on performance of a selected MCP family to that area.

Knowledge of MCP performance comes from full-sib progeny tests, which are only available through tree improvement cooperatives. Nonindustrial private forest landowners should be able to obtain information on

MCP families through companies such as ArborGen and International Forest Company.

The reason MCP seedlings are more uniform than open-pollinated seed orchard seedlings is rather simple. In open-pollinated seedling production, trees can be fertilized by pollen from poor-performing parents within the orchard or by non-improved parents outside of the orchard. Pollen not originating from individuals within the orchard is referred to as contaminating pollen.

In the late 1980s, a number of forestry companies and cooperatives throughout the South investigated the amount of outside pollen contaminating seed orchards. Depending on weather conditions and when female flowers were receptive, the amount of contamination could range from 10 to 80 percent of the total pollen load. Typically, this contaminating pollen resulted in lower genetic gains.

At the same time MCP techniques were being developed, a number of companies were also investigating the possibility of using pine clones as operational planting stock. Hedging and somatic embryogenesis were the two pathways pursued for a number of years.

Hedging is accomplished by growing specific individuals in pots and periodically removing newly developed growth for rooting purposes. The performance of rooted cuttings is hard to quantify because the individual seedling used to create the hedge is genetically unproven. Cuttings produced from a specific hedge are genetically identical. In addition, hedges tend to mature over a 4- to 5-year period, causing a dramatic drop in rooting and forcing a rejuvenation process.

Because of these limitations, the majority of pine clones, referred to as varietal stock, are operationally produced through somatic embryogenesis (SE). This removes the immature embryo and forces it to multiply. These somatic embryos are then grown into trees. Seedlings developed from a specific embryo are copies of one another. Because long-term storage is possible through cryopreservation (preservation through freezing), it is possible to market only progeny-tested varietal stock (SE material).

Although pine varietal production is not as simple as with eastern cottonwood (*Populous deltoides* W. Bartram ex Marshall), techniques and systems have been developed to mass-produce this type of planting stock. Availability of varietal pine planting stock is currently limited because production techniques are so costly. Current cost varies from $380 to $435 per thousand seedlings. With time, the price may drop so that this planting stock is more affordable.

Using varietal stock is unique because you can select the specific individual desired and know that each tree will be genetically identical. With uniform environmental conditions, this potentially gives more control over quality factors and growth rates. Testing is still ongoing to determine varietal selection for specific areas, optimal planting density, and silvicultural techniques needed to optimize production.

Currently, varietal stock is available through ArborGen, but you should check on testing and performance in your area. Varietal stock is more uniform, so you will not need to plant as many trees per acre. But be cautious and plant only on the very best sites if using this most expensive planting stock. Somewhere between 400 and 450 trees per acre is suitable. A planting mixture of higher priced varietals in combination with lower priced second-generation seedlings allows an early thinning, leaving only varietals for sawtimber production.

If you plant higher quality genetic stock, you also should increase your silvicultural management techniques. Planting fewer trees means survival needs to be close to 100 percent. Site preparation techniques and early competition control must be effective, allowing trees to express their full potential. In addition, you must control pine tip moth (*Rhyacionia frustrana* Comstock) and pine sawfly (*Neodiprion* spp.) to ensure rapid growth.

Hardwood Planting Stock

High site preparation and establishment costs combined with the long rotations needed to produce high-valued quality hardwoods slowed development of genetically superior hardwood planting stock. While some advances were made, these were primarily in fast-growth hardwood species such as eastern cottonwood.

The U.S. Forest Service Southern Hardwood Laboratory in Stoneville, Mississippi, developed genetically superior eastern cottonwood clones from the mid-1960s to the mid-1980s. This material was well suited for the Lower Mississippi Alluvial Valley, and a number of companies planted considerable acreage to this type of stock. Eastern cottonwood became the chief species of hardwood tree improvement as the first operationally planted clonal species. Today, very little eastern cottonwood is planted in the United States, but it is still a key species worldwide as either a planted species or a parent in the production of hybrid poplars.

Heavy-seeded species such as oaks have not received the attention that fast-growth hardwoods did in the past. For this reason, only limited improved material is available. In general, there are a number of reasons for the lack of tree improvement effort in many hardwood species:

- no single widely adapted species
- a wide variety of hardwood species
- the high cost of establishment
- an excess supply of low-cost hardwoods

Originally, hardwood tree improvement followed the same system that was successful in southern pines. Unfortunately, intensive selection of hardwood trees in native stands resulted in very little genetic gain. Reasons for this included a lack of comparison trees, considerable environmental influence, clonal propagation of some species, and site specificity.

Following the first round of selection of the best trees in native stands, seed orchard establishment, and early testing of seed orchard parents, it became obvious that this strategy yielded only limited genetic gain. To overcome this problem, tree improvement scientists shifted toward uniform testing that put less emphasis on intensive selection in natural stands and more emphasis on collecting a larger test population.

Additional problems were encountered in operating successful hardwood orchard programs because seed crops of many species are unreliable and seed storage is difficult. These difficulties delayed progress in hardwood tree improvement.

While hardwood genetic information is difficult to obtain, anyone purchasing seedlings should inquire about the geographic source of seedlings. Many experts advise using local seed sources. What most landowners and foresters are not aware of is that "local" typically means within a 150-mile radius of the planting site. "Local" also refers to the source of seed, not location of the nursery. It is important to note that using local seed typically provides adaptability but not necessarily any type of improvement.

Unlike the pine tree improvement cooperatives, the two hardwood tree improvement cooperatives located in the South were small and their research limited. Today, only the Western Gulf Tree Improvement Program continues to invest in a hardwood tree improvement program. This group, along with various state agencies, has established a number of oak orchards in Arkansas, Louisiana, Mississippi, and Texas. Very little of this improved seed is being collected currently.

Seed orchards of cherrybark oak and Nuttall oak (*Q. texana* Buckley) are located in Winona, Mississippi, and were established in cooperation with the Mississippi Forestry Commission. The cherrybark oak orchard currently produces a significant number of improved acorns, which are well suited for sites throughout Mississippi and other southern and midsouth states. Other cooperators in the Western Gulf Tree Improvement Program are producing oak species such as water oak (*Q. nigra* L.), Shumard oak (*Q. shumardii* Buckl.), and Nuttall oak.

For biomass production, genetically improved fast-growth hardwood species such as eastern cottonwood and sweetgum (*Liquidambar styraciflua* L.) are available. Improved cottonwood clones are available as unrooted dormant cuttings, and a great majority of these originate from Mississippi.

Like most hardwoods, cottonwood performs best on highly fertile, unstructured soils. Soils that have some type of pan are typically not well suited to fast-growth hardwood species. However, it is encouraging to note that new research efforts in eastern cottonwood, black willow (*Salix nigra* Marsh.), red maple (*Acer rubrum* L.), and American sycamore (*Platanus occidentalis* L.) are being undertaken in Mississippi to determine feasibility of these hardwood species for biomass production.

Conclusion

It is important to understand the genetic background of seedlings you plan to use in establishment of your next stand. Today, a wide variety of pine genetic material is available, ranging from open-pollinated seed to varietal seedlings. Each level of improvement is accompanied by a higher cost.

Landowner objectives and site quality are key components that should be used to determine the level of genetic improvement of seedlings desired for outplanting. For loblolly pine, cheaper second-generation seedlings should be used for areas of low site indices, while more expensive MCP and varietal seedlings can be used to provide quality timber on areas with higher site index.

With hardwoods, matching the species to the site is the first step to successful establishment. You should then determine if improved genetics are available for the selected species. If no improved material is available, try to use a local seed source. These seedlings will be adapted to local climatic conditions and resistant to local diseases. If improved hardwood seedlings are available, these can be used within the recommended geographic area.

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Glossary

Advanced-generation: Advanced-generation tree improvement is considered to be any breeding cycles beyond the first generation.

Backward selection: Selection of parent trees based on results of a progeny test. The information provides the genetic worth of parents.

Breeding population: A group of individuals selected for use in a breeding program. The group is selectively bred, tested, and culled in order to increase the mean genetic value for a desired trait or traits.

Clone: Refers to a group of genetically identical individuals. These individuals are derived asexually from a single individual genotype. "Varietal" is another word for clone.

Cryopreservation: Maintenance of the viability of excised tissues or organs at ultra-low temperatures (-196°C; i.e., temperature of liquid nitrogen); a technique for freezing cells to preserve for later use.

Cuttings: Vegetative material, usually a portion of a stem, limb, or root, that is used to propagate a selected individual. Unrooted cuttings are used in eastern cottonwood to clonally propagate selected individuals.

Genetic gain: These represent the improvement in traits such as growth, form, disease resistance, or wood characteristics that are made from breeding and selection.

Genetic quality: This term refers to the improved characteristics of the seedling. Non-improved or woods-run seedlings have little to no genetic quality. Genetic quality increases with increased selection and testing intensity.

Family: A group of individuals directly related by descent from a common ancestor.

Family forestry: Tested open-pollinated, polycross, or full-sib families that are deployed as single families in a plantation scenario.

Full-sib seed: This is the result of a control-pollinated mating of a known male and female.

Generation: In practice, there are seldom distinct generations except at the very early stage of breeding. In forestry, we designate first, second, and third generations.

Genetic diversity: Genetic variation present in a population or species.

Genetic testing: Planting a replicated field trial using offspring or other relatives, then measuring their exhibited traits as a means of estimating genetic value.

Genetic variation: Refers to genetic information segregating within a species. The genetic information is coded by genes, which reside on chromosomes.

Genotype: The specific set of genes possessed by an individual, both expressed and recessive.

Genotype-environment interaction: Changes in rank or level of performance among genetic entries when tested in different environments.

Heritability: In general, this is the degree that a progeny resembles its parents. It is also expressed as the ratio of genetic variance to phenotypic variance.

Improved material: Any seed or seedlings that result from a defined genetic breeding and testing program.

Local seed source: Source native to the locality where the seedlings are to be grown; defined as being within 150 miles of the planting site.

Mass-control pollinations: This is the commercial production of control pollinations where a selected mother is bred to a selected father, producing a full-sib family. A full-sib family can be considered intermediate between traditional open-pollinated seed and varietal (clonal) stock. The result of this breeding is a more uniform group of seedlings over open-pollinated seedlings. Mass-control pollination is synonymous with supplemental-mass pollination.

Mating design or mating scheme: The pattern of pollinations set up between individuals for a specific breeding program designed to evaluate specific type of genetic variation.

Natural stands: A native stand of trees; those that were not artificially regenerated.

Open pollination (OP): Natural pollination that is not controlled but rather occurs due to wind or insects. An open-pollinated family is typically a mixture of selfs, full-sibs from a few adjacent trees, and crosses resulting from unknown pollen parents.

Phenotype: The observed characteristics of an individual. The phenotype is determined by the genotype interacting with the environment in which it is grown. Therefore, Phenotype = Genotype + Environment or P = G + E.

Ramet: A vegetatively reproduced copy of a specific genotype or clone. Each ramet will have (almost) precisely the same genotype as the original parent tree.

Rejuvenation process: Methods employed to reverse the maturation (aging) process and allow more successful rooting of an individual.

Roguing: The removal of genetically undesirable individuals from breeding, testing, or production populations; this is done so that these individuals no longer pass on any unwanted traits.

Seed orchard: Production population managed for seed production.

Seed source: A term referring to seed collected from trees from a specific geographic region or physiographic area.

Sibs (siblings): Offspring that have one or both parents in common. Full sibs have both parents in common, whereas half sibs have only a single parent in common.

Somatic embryogenesis (SE): Somatic means descriptive of nonreproductive cells and/or cell divisions. Embryogenesis is the formation of an embryo from a zygote. Somatic embryogenesis is a technique to duplicate selected trees asexually from their vegetative cells, which allows the best trees to be immediately propagated commercially as varietal (clonal) stock.

Unstructured soils: Soils that lack aggregation or arrangement of the primary soil particles.

Varietal: Refers to a group of genetically identical individuals. These individuals are derived asexually from a single individual genotype. “Clone” is another word for varietal.

Varietal forestry: This is where the best individual from the best set of parents is selected. After selection, millions of identical copies (clones) of this best individual are produced through a varietal production process.

Vegetative propagation: Propagation of a tree by asexual means, such as budding, grafting, and rooting, of some part of the tree.

Glossary definitions from *Glossary for Forest Tree Improvement Workers* (Snyder, 1972).

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