Choose Your Planting Stock Carefully

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 the 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 spend time thinking about the genetic quality of the seedlings they will be planting.

Most landowners and professional foresters consider open-pollinated second-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, open-pollinated third-generation seedlings, full-sib seedlings, and clonal stock.

Unlike pine, the genetic quality of most hardwood planting stock is severely limited. Most of the genetic advances have been made with fast-growth hardwoods that have proven 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 length of rotation, limited site adaptability, and inability to regenerate through vegetative propagation. For these types of hardwoods, genetic improvement has followed the seed orchard scenario developed in pine.

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

Historical Seed Orchard Information

In Mississippi as well as 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 across the southeastern United States. These first-generation orchards were constructed from mature selections taken from natural stands and then grafted into an orchard setting.

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

The removal of the poorer performing parents from the orchard based on their progeny performance is termed roguing. The resulting rogued orchard is

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referred to as a 1.5-generation seed orchard. The significance of a rogued orchard is that only the best of the best parents remain in the orchard, which should theoretically increase genetic gains.

The majority of the 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 just as was done in the first-generation orchard, progeny testing of the second-generation orchard provides the capability of eliminating 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- (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

The development of improved planting stock for the southeast U.S. was primarily driven through the tree improvement cooperatives located at North Carolina State University, University of Florida, and the Texas Forest Service. A variety of state forestry agencies and industrial companies were members of one or all of these cooperatives. Some of the larger forest companies, while belonging to a cooperative, may have also had their own tree improvement programs.

Over the last 15 years, the forest industry has seen consolidation, and the majority of the remaining companies have sold their land base. To counter this, many companies signed fiber contracts with the purchasing groups to ensure a flow of fiber to their mills. Most companies emphasized growth of their plantations, with only limited regard for form or quality.

In the late 1980s, the forest 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. These single-family plantings are defined as the collection of seed from a single parent from a specified orchard. Thus, all of the seedlings developed from the seed of a single family share the same mother, but the pollen parents (i.e., fathers) are unknown.

To take advantage of the genetic uniformity that a single family provides requires the ability to track that family performance through time on that specific site. This in turn led many forestry companies in the southeast to invest in an intensive land classification system, which would complement their genetics program as well as provide information that could be used to determine the feasibility of silvicultural techniques and lower growing costs. While such a system was rather time-consuming, it did provide a wealth of information on soil type, structure, nutrients, moisture availability, vegetative management, and geologic information.

A land classification system in combination with extensive genetic testing led to the mosaic of single-family plantings, which soon became the norm for many forest companies across the South. The reduction in genetic diversity of a single-family planting has been questioned both within as well as outside of the forest community. However, there have been no problems associated with limiting the genetic variation in plantations by planting single families to specific sites. 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. The advanced-generation seed produced by MFC was collected from orchards located in south Mississippi. These orchards were devised for two planting zones, known as North and South Loblolly Zones (http://www.mfc.ms.gov/publications.html).

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 cases, 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 variable environmental effects and site quality differences. These guidelines were a conservative approach taken because of variable site quality and management differences among landowners, as well as the inability to track specific parental performance over numerous sites within each planting zone.

Newly Improved Planting Stock Types

As information was being sorted out as to what second-generation parent companies wanted to deploy, new advanced-generation material was being bred. The resulting progeny was included in tests.

The performance of these full-sib progeny from the advanced-generation testing phase initiated interest in the use of full-sib seedlings as a 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 type of seed was that there wasn't enough seed 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). The result of using MCP seedlings is greater uniformity in growth, form, and disease resistance.

Currently, MCP or SMP is available through some nurseries at approximately $60 to $80 per thousand higher than the typical second-generation open-pollinated seedlings. To take advantage of MCP seedlings, you at least need information on the parental performance in a specific area. It is even better to have information on the performance of a selected MCP family to that area.

Knowledge of MCP performance initially comes from full-sib progeny tests, which are only available through the tree improvement cooperatives. Non-industrial private forest landowners should be able to obtain information on MCP families through companies such as ArborGen, LLC.

The reason MCP seedlings are more uniform than open-pollinated seed orchard seedlings is rather simple. In an open-pollinated case, trees can be fertilized by pollen from poor parents within the orchard or, in the worst case, with non-improved parents from 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 coming into the orchard. Depending on weather conditions and when female flowers were receptive, the amount of contamination could range from 10 to 80 percent. 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 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 and rooting this material. The performance of rooted cuttings is complicated by the fact that the individual seedling used to create the hedge is genetically unproven.

The 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 pine varietal stock, are operationally produced through somatic embryogenesis (SE). This is done by removing the immature embryo and forcing it to multiply. These somatic embryos are then grown into trees. The seedlings developed from a specific embryo are copies of one another. Because long-term storage is possible through a process called cryopreservation, it is possible to market only progeny-tested varietal stock (SE material).

Although pine varietal production is not as simple as eastern cottonwood, techniques and systems have been worked out to mass-produce this type of planting stock. But availability of varietal pine planting stock is currently limited because the production techniques are so costly. The current cost can vary 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 should give you 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 CellFor and ArborGen, but you need to check on testing and performance in your area. Because varietal stock is more uniform, you will not need to plant as many trees per acre. But be cautious with this approach and plant only on the very best sites. Somewhere around 400–450 trees per acre might be suitable. A planting mixture of higher-priced varietals in combination with lower-priced second-generation seedlings will allow an early thinning of the second-generation seedlings, leaving only the 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 the trees to express their full potential. In addition, you must control pine tip moths (*Rhyacionia frustrana* Comstock) and pine sawfly larvae (*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 also slowed the development of genetically superior hardwood planting stock. While some advances were made, these were for the most part with fast-growth hardwood species such as eastern cottonwood.

The U.S. Forest Service Southern Hardwood Laboratory in Stoneville, Mississippi, developed genetically superior eastern cottonwood (*Populus deltoides* Bartr.) 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 shining star of hardwood tree improvement as it became the first operationally planted clonal species, with the planting stock of choice being dormant unrooted cuttings. 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 as 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
- few effective chemicals for competition control
- an apparent endless supply of low-cost hardwoods

Originally, hardwood tree improvement followed the same system that was so successful in southern pines. Unfortunately, intensive selection of hardwood trees in native stands resulted in very little genetic gain. The 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 met with only limited success in terms of 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 and left many thinking that little genetic gains could be made in hardwoods.

While hardwood genetic information is difficult to obtain, anyone purchasing seedlings should at least inquire about the geographic source of the seedlings. Many experts advise using local seed sources. What most landowners and foresters don't realize is that the term "local seed source" incorporates a 150-mile radius from the planting site. "Local" also refers to the source of the seed, not the location of the nursery. But 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 rather small, and their research was limited. Today, only the Western Gulf Tree Improvement Program continues to invest in a hardwood tree improvement program. This group, along with 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 (*Q. pagoda* Raf.) and Nuttall oak (*Q. nuttallii* Palmer) are located in Winona, Mississippi, and established in cooperation with the Mississippi Forestry Commission. The cherrybark oak orchard is currently producing a significant number of improved acorns, which are well suited for sites throughout Mississippi and other southern and mid-south states.

Heavy seed crops were produced in 2009 and 2010. The Elberta Forest Tree Nursery in Alabama collected this improved cherrybark oak seed during the fall of 2009. This effort should produce the first crop of genetically improved cherrybark oak seedlings on the market for the 2011 planting season. This is significant because no other southern state is producing genetically improved cherrybark oak seed. 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 species such as cottonwood and sycamore. However, it is encouraging to note that new research efforts in eastern cottonwood, black willow (*Salix nigra* Marsh.), red maple (*Acer rubrum* L.), and sycamore are being undertaken within Mississippi to determine the feasibility of these hardwood species for biomass production.

Conclusion

It is important to understand the genetic background of seedlings you plan to use in the establishment of your next stand and whether these seedlings are compatible with your management objectives. Today, a wide variety of pine genetic material is available, ranging from open-pollinated seed to varietals. 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 seedlings and varietals can be used to provide quality timber on areas with a higher site index.

With hardwoods, matching the species to the site is the first step you need to take. You should then determine if the selected species has improved genetic seedlings available. If no improved material is available, at least make sure you use a local seed source. These seedlings will be adapted to the local climatic conditions and resistant to any 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 synonymous with the term 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 the 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 non-reproductive 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. Varietal is another word for clone.

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
https://fp.auburn.edu/sfws/sfnmc/class/glossary.html
http://www.esf.edu/for/maynard/GENE_GLOSSERY.html
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Publication 2589
Extension Service of Mississippi State University, cooperating with U.S. Department of Agriculture. Published in furtherance of Acts of Congress, May 8 and June 30, 1914. MELISSA J. MIXON, Interim Director (POD-01-10)