What Are Genetically Improved Seedlings?

MISSISSIPPI STATE UNIVERSITY EXTENSION

An understanding of genetics is a powerful tool when used correctly. This understanding has played and will continue to play a major role in many areas of human life, from food to medical needs and beyond. Some of the most sophisticated, cutting-edge genetic technology is used in pine improvement programs in the southern U.S. Improved seed, seedlings, and trees have proven their worth for more than 40 years.

Genetically superior seedlings increase timber revenue because of their faster growth rates, greater adaptability, increased disease resistance, improved wood properties, and superior form. Planting trees for timber production is a common practice in the South. Previously, Mississippi landowners could get seedlings from either state or private sources. Mississippi Forestry Commission nurseries were closed in 2008, so landowners now have to choose seedlings from private nurseries across the South.

These nurseries offer similar levels of genetic improvement (such as 1.5- and second-generation seedlings), but the products may not have been thoroughly tested in Mississippi. Mississippi landowners have to research available seedlings and their performance for sites to be regenerated. The choice of what to plant often depends on your resources and goals. This publication will help you understand the various types of genetically improved seedlings available, the terminology, and seedling cost.

What Is a Genetically Improved Tree?

Simply stated, a genetically improved tree comes from a strict selection process where progeny (offspring) produced by the tree show superior performance for a specific trait (such as growth or form) or a combination of traits. Typically, offspring of a genetically superior parent tree are tested and closely evaluated across a wide variety of sites over a number of years. This eliminates as much environmental influence as possible and reveals the true genetic worth of the parent.

The first step in developing genetically superior individuals is screening the natural population for specimens exhibiting traits you want (such as fast growth). Branch tips of these selected individuals are grafted onto rootstock seedlings and placed into an orchard known as a first-generation seed orchard (Figure 1).

Typically, 25 to 30 selected individuals are grafted into this orchard. These 25 to 30 individuals are placed where there is good pollen flow and, hopefully, an equal chance of random pollination. Depending on the species, it may take 3 to 10 years for grafted trees to produce seed. Seed produced from the orchard and resulting seedlings are genetically improved and represent first-generation improvement.

While these seedlings represent a specific level of improvement, this level can be easily increased by testing the resulting progeny to determine the best parents. This type of progeny testing allows the orchard manager to rank the genetic worth of the parents and eliminate lower-ranking individuals from the orchard, thus increasing genetic gain. Thinned orchards are called half-generation orchards; this is represented numerically as .5, so a thinned first- or second-generation orchard would be called a 1.5 or 2.5 orchard, respectively.

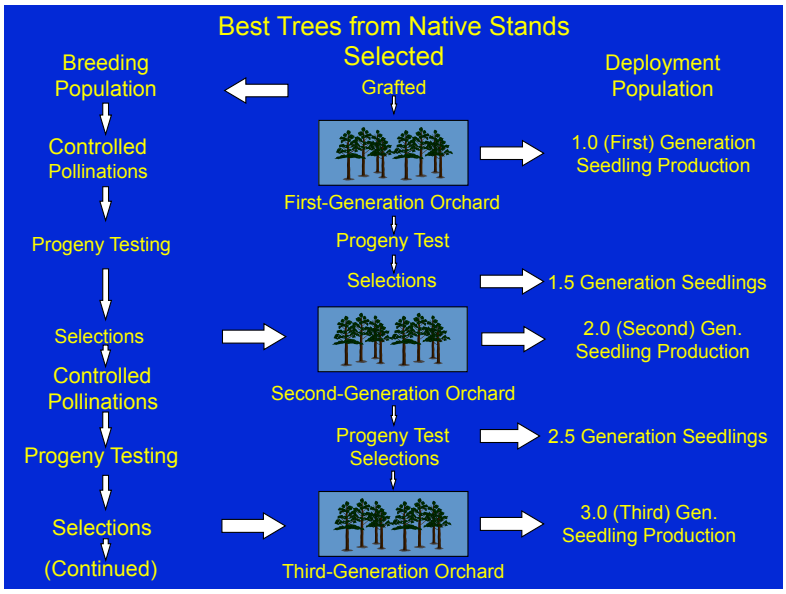

Figure 1. Generalized flowchart showing how genetically improved seedlings are developed through three generations.

At this point, genetic gains can be increased only through breeding and selection. During the selection process, a much larger breeding population is selected. This larger group of individuals allows a much greater variety of controlled breeding and is the foundation of seed orchards for future generations.

Seedling Terms

A variety of terms describe the level of genetic improvement as well as types of seedlings. Here are some of them:

- **First-, second-, or third-generation seedlings**. These terms represent progression of tree improvement, with first-generation seedlings being produced from initial selections within natural stands, followed by second- and third-generation seedlings produced from selections developed through specific matings.
- **Bare-root seedlings**. Seedlings grown in a nursery bed, machine lifted, and bundled in bags or boxes. Most pine and hardwood seedlings are sold as bare-root stock.
- **Low-density seedlings**. Low-density seedlings have a larger, more developed shoot and root system. They are usually more expensive than typical bare-root seedlings. Typical bare-root seedlings are grown in nursery beds at 25 seedlings per square foot, while low-density seedlings are grown at 18 or fewer seedlings per square foot.
- **Containerized seedlings**. Seedlings grown in some type of container. The size and type of container can vary from small plastic tubes to pots. Seedlings grown in containers have a more intact root system and are more expensive than bare-root stock. In general, containerized pine seedlings are removed from the container and placed into boxes, which are then placed into cold storage until planted. They provide a wider planting window and have been shown to have higher survival under stressed planting conditions. If the seedlings remain in the container, they can be planted while actively growing.
- **Mass control-pollinated (MCP) seedlings**. These full-sib seedlings come from mating specific parents (control-pollinated). Although grown in nursery beds, they are more expensive than regular first-, second-, or third-generation seedlings because of added breeding expense. MCP seedlings also yield greater genetic gains than regular generational seedlings.
- **Varietal stock**. These seedlings are genetically identical and can come from either vegetative propagation or somatic embryogenesis, where a single embryo is multiplied to produce millions of trees. Loblolly pine (*Pinus taeda* L.) varietal stock represents the current highest level of genetic improvement. It is expensive, costing 10 times more than regular bare-root seed orchard seedlings and four times more than MCP seedlings. However, if you make proper selections, genetic gains are much better than open-pollinated seed orchard seedlings or MCP seedlings. Varietal stock is typically sold as containerized material.

Why Plant Genetically Superior Seedlings?

Any reduction in time needed to grow a high-quality tree with improved characteristics means more profits. In fact, profits from tree improvement have generally been high because of both the modest price of improved seedlings and increased forest productivity and value realized from planting improved stock. Two questions that arise are "What is the best genetic material worth?" and "What are the financial benefits of planting the best genetic material?"

A rule of thumb has been that improved genetic seedlings have approximately a 10 percent gain in volume growth over unimproved seedlings. More recent estimates showed second-generation pine seed orchards throughout the South have doubled gains from the first generation. If you consider only the best open-pollinated (OP) families from rogued seed orchards, estimated genetic gains in volume growth are even higher, from 26 to 35 percent. MCP (full-sib) families from the best second-generation parents can produce more than 50 percent volume gains. When you add improvements in stem form and disease resistance, stand value improvements may be twice the volume improvement.

Varietal pine planting stock currently represents the highest level of genetic improvement. "Varietal" refers to clonal production, so if you order a single specific varietal seedling type, you receive a single clone. As an example, if you want to use a single varietal on your 20 acres and want to plant 500 trees per acre, you would receive 10,000 genetically identical seedlings. Today, varietal pine planting stock can be from either somatic embryogenesis or hedging, where shoot tips are rooted and grown into seedlings. The process is extremely costly, making varietal planting stock very expensive. Before you commit to buying and planting varietal pine planting stock, research the testing of that specific individual in your geographic area.

Genetically improved hardwood cuttings for eastern cottonwood and seedlings for American sycamore and sweetgum are available mostly for short-rotation pulpwood plantation programs by the pulp and paper industry. Genetic studies on a variety of oak species are continuing, but progress has been rather slow; however, genetic gains in both cherrybark and Nuttall oaks have shown promise with very limited seedling availability.

The Mississippi Forestry Commission's cherrybark and Nuttall oak orchards are now producing genetically superior seed. However, these two orchards have been idled, and only improved seedlings of the two species are available through the Western Gulf Tree Improvement Program at Texas A&M.

What Are the Limitations?

The Southern Forest Tree Improvement Committee issued a position statement in 1990 for loblolly pine. Some points are still valid today:

- Uninformed use of a local seed source is not necessarily the best or safest choice.
- Genetic differences among seed sources let informed landowners increase yields by wisely matching nonlocal sources to specific planting environments.

Use of improved stock should be matched with silvicultural practices that reduce environmental stress, such as controlling weeds and insects. If such practices are not used, financial risks are greatly increased. Individual open-pollinated families, full-sib families, and selected clones of loblolly pine display remarkable stability and predictability of growth performance across sites in the southern United States. As long as seedlings are matched to the proper climatic zones, family performance is rather stable.

The forest industry is using improved genotypes bred from MCPs in order to maximize genetic gains. This genetic material produces much higher gains, and many foresters are willing to plant fewer families on specific sites to capture them. To date, no disease or insect problems have been associated with planting more advanced genetic stock.

However, planting single families could be a mistake. If a nonindustrial private forest landowner (NIPF) uses natural regeneration after a single-family planting, genetic diversity can be reduced too much. In only one or two cycles of natural regeneration, inbreeding could seriously reduce growth and productivity.

Since the Mississippi Forestry Commission (MFC) no longer produces pine seedlings, landowners have to research the type of seedlings they should be purchasing for regeneration. While a loblolly seed orchard mix has been preferred for Mississippi landowners in the past, knowing the performance of specific loblolly parents can provide additional gains. Landowners should ask for a performance rating sheet (PRS), which provides information on growth, stem form, and disease resistance. This information can quickly allow you to judge if seedlings are right for your conditions.

Orchard mixes were recommended because of the variety of sites throughout Mississippi and limited genetic testing. This was a very conservative recommendation with very little risk but yielded lower genetic gains and increased susceptibility to fusiform rust. Now that we know more about soils and site characteristics, we recommend single-family plantings regardless of whether they are open-pollinated or control-pollinated. Landowners should remember that proper silvicultural treatments are required to yield higher genetic gains.

Without doubt, the major limitation of using hardwoods is matching species to the site correctly. Genetically superior hardwood seedlings will not provide increased yields if the species is not suited to the site. Because there is a lack of genetically superior hardwood seedlings, it is extremely important to understand seed source differences. Landowners typically use local seed sources for hardwoods. However, southern seed sources in hardwoods tend to be superior to northern sources.

Before purchasing any hardwood seedlings, request information on seed source origin. If this information is not available, it is usually best to avoid these seedlings. Also, competition control remains extremely important for genetically superior hardwood seedlings. These seedlings will not outcompete weeds for nutrition and moisture.

Sources of Seedlings

Mississippi landowners have several sources for seedlings. MTN 4E Forest Seedling Availability from In-State and Regional Nurseries lists several nurseries in Mississippi and neighboring states. You can request a copy of this list by emailing john.kushla@msstate.edu.

Remember that it is your responsibility to be informed about seedlings you order. It is also important to order seedlings early because nurseries often sell out by planting season. If you are planning to use state or federal cost-share funds or the Mississippi reforestation tax credit for forest tree planting on your land, an MFC area forester must approve the source of your seedlings.

Site Preparation, Seedling Care, and Management

Once you have ordered seedlings for the upcoming planting season, the work begins. It is extremely important to understand what types of site preparation are necessary to ensure seedlings survive and express their full genetic potential. If you are planting retired agricultural fields, subsoil the site to break up any existing traffic pan and provide a better planting area. If planting follows a timber harvest, you can use chemical and mechanical techniques to provide a suitable environment for regeneration.

When ordering seedlings, make sure you know exactly how they will be shipped. Ask the nursery to notify you before shipping so you can store them appropriately when they arrive. Proper seedling care is critical. Arranging for proper storage of seedlings is important if you cannot plant immediately. Typically, seedlings are stored at 34–40°F and at a relative humidity of around 80 percent. Do not put seedling bags in the sun or where wind can dry out the root systems.

Use proper planting techniques to ensure seedlings survive and grow. When using bare-root seedlings, make sure the planting hole is deep enough to insert the seedling roots in a straight position and that soil covers the root collar. Next, close the hole so the seedling is wedged tightly in the soil, making sure no air pockets are left that may dry out and kill roots. Containerized seedlings are planted using the same method, but specialized planting tools may be needed. Hardwood seedlings tend to be much larger than pine seedlings. To create a larger planting hole, use a larger, broader dibble or planting spade.

You must prepare the site properly and use vegetation management techniques to give seedlings the best chance for survival and growth. Your local Mississippi Forestry Commission area forester, consulting forester, or MSU Extension agent can provide information and guidance on what procedures to follow on your land.

Conclusion

Using genetically improved seedlings is one of the most cost-effective decisions you can make when regenerating forest stands. Today, a wide array of improved pine seedlings is available from a variety of nurseries. These seedlings range from open-pollinated to mass control-pollinated to varietal stock. With every level of genetic improvement, potential genetic gain increases greatly. To realize this gain, you must use increased levels of silvicultural intensity.

Currently, varietal stock is the highest level of genetic improvement available, but performance data over a wide variety of Mississippi sites is very limited. The cost of varietal pine is approximately four times the cost of second-generation open-pollinated seedlings. Understanding where varietal stock is most cost-effective is important in trying to maximize return on investment.

It is critically important that hardwood species are matched to site conditions. Once you decide what hardwoods to use on a specific site, choose the highest level of genetic improvement you can afford. With hardwoods, genetic improvement varies greatly from the clonal production of eastern cottonwood to that of first-generation cherrybark oak.

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