RELATING NURSERY TO FIELD PERFORMANCE OF SHORTLEAF PINE SEEDLINGS

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Abstract.--When defined in terms of field performance, stock quality is a function of the seedlings' potential to survive and grow after outplanting. Seedling quality represents a complex integration of physiological and morphological characteristics. These seedling characteristics can be markedly altered by the application and timing of cultural practices in the nursery. Based on a literature review and discussions at the first meeting of the Task Force on Shortleaf Pine Artificial Regeneration in the Ouachita and Ozark Mountains, a shortleaf pine target seedling is described.

Additional keywords: artificial regeneration, seedling quality, Pinus echinata

In recent years planting stock quality has received considerable attention. A IUFRO workshop entitled "Techniques for Evaluating Planting Stock Quality" was held in New Zealand in 1979 and subsequently an issue of the New Zealand Journal of Forestry Science (Vol 10, number 1) served as a proceedings of that meeting. In 1984 another workshop, entitled "Evaluating Seedling Quality: Principles, Procedures, and Predictive Abilities of Major Tests," was held at Oregon State University. A proceedings of that meeting was also published (Duryea 1985). The level of interest in this topic reflects the biological, economical, and managerial importances of getting plantations off to a good start.

To foresters, the ultimate measure of seedling quality is field performance. When defined in terms of field performance, stock quality is a function of the seedlings' potential to survive and grow after outplanting. Seedling quality represents a complex integration of physiological and morphological characteristics and, therefore, cannot be measured easily. Also, stock quality must be defined for a specific point in time, because subsequent handling, storage, or planting can have a tremendous impact on potential field performance.

Attributes of seedling quality can be grouped into 2 categories, material attributes and performance attributes (Ritchie 1984). Material attributes are directly measurable morphological or physiological characteristics such as root collar diameter, dry weight, foliar nutrient content, and plant moisture stress. Wakeley's (1954) morphological grading standards for southern pines fall into this category. When several material attributes are considered together they can be useful for describing potential field performance. Individually, however, these attributes have little predictive value unless they are well outside the normal range, such as pine seedlings with very small, < 3 mm (1/8 in), root collar diameters.

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Performance attributes are whole-seedling measures of response to particular test conditions. Examples include testing for root growth potential and cold hardiness. Such tests are good predictors of field performance. However, they often require 3-4 weeks to complete, and therefore the results are usually not timely enough to aid in making management decisions. Performance attribute testing is extremely valuable, however, when used to evaluate nursery culture and then to apply the results toward improving future crops.

SHORTLEAF PINE SEEDLING QUALITY

The most widely accepted standards for describing southern pine bareroot stock are Wakeley's (1954) morphological grades. These grades emphasize root collar diameter and classify as cull any shortleaf pine (Pinus echinata Mill.) seedling with a ground line diameter of less than 3.2 mm, (1/8 in), (Table 1). Recognizing the effect that the basal crook can have on root collar diameter, Chapman (1948) recommended a diameter of 2.5 mm (2/20 in) at 2.5 cm (1 in) above the ground line as the lower limit of plantable shortleaf pine seedlings.

Table 1.--Specifications of morphological grades of uninjured 1-year-old shortleaf pine seedlings (Wakeley 1954)

Grade	Root collar heights	Root collar diameter	Nature of stem	Bark on stem	Needles	Winter buds
	cm (in)	mm (in)				
1	10-25 (4-10)	About 4.8 (3/16)	Stiff, woody. Usually a crook at ground level; often branching	Usually on entire stem	Almost entirely present in 3's and 2's	Usually present
2	7.5-15 (3-6) sometimes 20 (8)	About 3.2 (1/8)	Moderately stiff; often with crook and branches	On lower part at least; often all over	Part at least 3's and 2's	Occasionally present
3	Usually less than 10 (4)	Distinctly less than 3.2 (1/8)	Weak; often juicy; often straight	Often lacking	Practically all single, bluish	Practically never present

1/ Grades 1 and 2 usually considered plantable, and grade 3 culled.

2/ Any seedlings with roots less than 12.5 cm long should be considered as grade 3 (culls), regardless of the quality of the tops.

Wakeley's morphological grades were developed after years of observing the survival and growth of seedlings that had various morphological characteristics when they were planted. In general, the distinction between plantable and cull seedlings is substantiated by outplanting success. However, there are enough exceptions that Wakeley (1949) recommended the development and adoption of physiological grades which better reflect survival and growth potential. He suggested measuring such physiological attributes as nutrient content, stored food reserves, and seedling water status. Since Wakeley's time, much progress has been made in the physiological evaluation of planting stock, with root growth potential receiving most of the attention (Stone 1955, Stone and Jenkinson 1971, Burdett 1979, Ritchie 1985). None of this important work has been done with shortleaf pine.

Although morphological grades have limitations, they have provided valuable insights into the importance of seedling quality. For his grading study, Chapman (1948) established shortleaf pine plantations on relatively poor quality, old field sites in southern Indiana and southern Missouri. Clark and Phares (1961) measured these plantations at age 19-21 and tound, depending on the site, that the large seedlings, 20-30 cm (8-12 in) tall and 5 mm (4/20 in) diameter at 2.5 cm (1 in), produced from 31 to 92 percent more volume per hectare than the small seedlings, 10-20 cm (4-8 in) tall and 2.5 mm (2/20 in) diameter. Much of the increased volume was due to better survival of the larger seedlings. Although the large seedlings grew tallest during the first 3-5 years, by age 19-21 no longer did significant height differences exist. The large seedlings had significantly greater d.b.h. at age 21 at the Indiana site, but in Missouri there was no relationship between seedling size and d.b.h. at age 19-21. Based on their results Clark and Phares agreed with Chapman's minimum plantable shortleaf pine seedling of 10 cm (4 in) tall and 2.5 mm (2/20 in) at 2.5 cm (1 in). However, for best results they recommended planting seedlings at least 15 cm (6 in) tall and 3.8 mm (3/20 in) in diameter at 2.5 cm (1 in) above the root collar.

In another study, shortleaf pine seedlings selected from 3 nurseries over a 4-year period on the basis of height only were compared at age 9-12 for survival, height, d.b.h., and volume per tree (Grigsby 1975). The study included 289 trials of small, 9 cm (3.6 in) tall, average, 18 cm (7.2 in), and large 30 cm (12 in) seedlings planted at 5 locations in southern Arkansas and northern Louisiana. With data combined across ages and sites no differences were found in survival; but the large seedlings were significantly better than the small seedlings in height, d.b.h., and volume, and also had significantly greater volume than the average seedlings.

DEVELOPING A TARGET SHORTLEAF PINE SEEDLING

Based on past research and years of observing planting results by field foresters, a shortleaf pine seedling ideotype-or target seedling-can be described. The concept of a target seedling should include the acceptable range for each attribute and be flexible so that it reflects the current state of knowledge. As more evidence is accumulated the target specifications should change. It must also be recognized that different target seedlings may be appropriate for different geographic locations or site characteristics.

The value of a target seedling is that it provides a goal for the nursery manager to work towards and a standard of comparison for the forester.

In December 1984, a group of 19 USDA Forest Service, industry, state, and university foresters and silvicultural researchers met to discuss ways to improve artificial regeneration success with shortleaf pine. This group formed the Task Force on Shortleaf Pine Artificial Regeneration in the Ouachita and Ozark Mountains. As a result of discussions at that meeting and the literature already reviewed, an initial target seedling was defined based, on morphological charateristics (Table 2). Material physiological attributes and performance attributes were not included because they have not been investigated in shortleaf pine. The meeting did set a research agenda that addresses other attributes, and as results become available the target seedling specifications will be refined and expanded.

Table 2.--Initial target seedling specifications for bare-root shortleaf pine seedlings to be planted on Ouachita and Ozark Mountain sites

Attribute	Specifications
Height	15-25 cm (6-10 in)
Root collar diameter	2.5-5.0 mm (0.1 - 0.2 in)
Root/Shoot ratio (ODWT)	> 0.40
Foliage	Mostly secondary needles
Stem	Woody
Terminal bud	Well developed by November 1
Root system	> 7 laterals, fibrous, mycorrhizal
Tap root	10-20 cm (4 - 8 in) long

PRODUCING SEEDLINGS OF DESIRED QUALITY

Seed Quality

The goal of the seedling producer is to grow as large a percentage of the crop as possible to target seedling specifications. The more uniform the crop, the easier it is to bring the greatest number to the desired quality. Crop uniformity requires sowing high viability seed lots. Seed viability can be markedly reduced by poor extraction, processing, or storage practices. In early studies which included shortleaf pine, Huberman (1940a) determined that the sum of all losses following germination was not nearly as great as the number of seeds that failed to germinate. Because laboratory germination was similar, he concluded that the problem was due to faulty extraction or storage. Modern methods and equipment make it possible to process and store pine seeds while maintaining high viability (Krugman and Jenkinson 1974).

The seeds that Huberman (1940a) used were not stratified. Shortleaf pine seeds exhibit dormancy and need stratification for rapid, uniform germination. Stratification for 56-70 days proved best when both speed and completeness of germination were considered over a range of stratification durations (Barnett and McGilvray 1971). Clearly then, uniform establishment in the nursery requires careful seed extraction and cleaning, followed by proper storage and then stratification for about 60 days before sowing.

Sowing regimes and seedbed density

To grow a crop of seedlings to target specifications requires a thorough knowledge of how those seedlings grow and respond to cultural manipulation. In a bare-root nursery, the first considerations are sowing date and seedbed density. After comparing several sowing dates from March to early May in central Louisiana over a 2-year period, Huberman (1940b) recommended sowing shortleaf pine before mid-April. Based on operational observations, TVA sowed shortleaf pine in March and early April at its nurseries in east Tennessee and northwest Alabama (TVA 1954).

Seedbed density has a tremendous impact on seedling morphology, especially stem diameter and root mass. With loblolly and slash pines, average root collar diameter decreases with increasing density (Shoulders 1961). In loblolly pine, as density increases root weight is reduced proportionately more than shoot weight, resulting in a corresponding decrease in root-to-shoot ratio (Harms and Langdon 1977). Wakeley (1954) stated the maximum density for shortleaf pine was 540-590 seedlings per square meter (50-55 per square foot). However, he also wrote that under favorable nursery conditions such densities would result in about 20 percent cull seedlings. Based on the results of his grading study, Chapman (1948) recommended a maximum of only 270 seedlings per square meter (25 per square foot). Considering the value of seed orchard seed and the current cost of labor for culling nursery stock, a density near Chapman's recommendation is more appropriate.

Seedling Growth and Development

Once seedlings become established in the nursery, they enter a rapid growth phase. In this phase the nursery manager encourages growth by maintaining adequate levels of soil moisture, by addition of nitrogen fertilizers, and by pest management procedures such as weed and disease control.

As seedlings approach the target height, cultural treatments are usually applied to limit shoot growth. Water and topdressing with nitrogen are withheld to induce sufficient stress to stop shoot elongation. Often stress alone will not halt height growth. Single or repeated undercutting of the seedlings has significantly reduced shoot growth, markedly increased lateral root development, and improved field survival of loblolly pine (Tanaka and others 1976). While stress can effectively control seedling height, too much stress will also limit diameter growth. Therefore careful monitoring of the crop is necessary to ensure that the level of stress applied will stop elongation without severely limiting diameter development.

Lifting

After high quality stock is produced, careful lifting and handling are essential to ensure good survival and growth after outplanting. Because shortleaf pine may not have as good storage potential as loblolly pine (Venator 1985), lifting schedules need to be closely coordinated with planting needs so that storage time can be minimized. Throughout lifting, handling, and storage operations, seedling roots must be protected from drying exposure, heat, extreme cold (freezing), and mechanical damage.

SUMMARY

The goal of reforestation should be to plant seedlings of the best genetic and physiological quality available for the site. This requires teamwork between the nursery manager and silviculturist. Nursery practices which have major impacts on seedling quality include soil management, seedbed density, control and protection of seedling development, and timing and methods of lifting. Between lifting and planting, a cool, moist environment is essential to maintain stock quality. Seedlings must be protected from heat, desiccation, and freezing during handling, storage, and transportation, and at the planting site.

The ultimate measure of seedling quality is field performance. Silviculturists and nursery managers need to be able to predict seedling performance based on characteristics that can be measured. Conventional morphological traits used to grade seedlings have provided some quality control, but an ability to assess physiological condition would provide a key to accurate prediction of nursery stock performance. Although several techniques have potential, an easy, reliable method for determining physiological quality of shortleaf pine seedlings is needed.

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