# LATERAL ROOT DEVELOPMENT—
# SEEDLING QUALITY—FIELD PERFORMANCE

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In the past two years, two more nursery manuals have been published to tell us in great detail how to grow and evaluate seedlings. In a large measure, they fail to do so. In these few pages I cannot do any better than those manuals could in a combined total of 500 pages (Duryea and Landis 1984, Duryea 1985).

The reason for failure is simple. While many can tell you how to grow big seedlings, no one can tell you what their field performance will be. For the past 50 years, researchers have been trying to relate performance after outplanting to attributes of a nursery seedling (Duryea 1985). In spite of all this effort, the Southern Industrial Forestry Research Council (1984) pointed out that clarification of factors relating to seedling survival and early recognition of superior individuals were the keys to increased fiber production and success in both the genetics and regeneration programs in the South.

I will not attempt to tell you how to manage your nursery to grow "quality seedlings". I don't know your specific problems, much less their solutions. Instead, I will discuss how seedling quality has been defined for the past several decades and then describe some potentially important observations on sweetgum seedlings. I believe that this research will eventually lead to a major change in the way we assess seedling quality and that a dominant feature in this assessment may be first-order lateral roots. I do not expect you to agree with all my speculations on this matter but I hope you will begin to look beyond the size of a top when you are evaluating your seedling production.

### *Background*

"Seedling quality" and "quality seedlings" probably have been among the most often printed phrases in forestry literature for the past several decades. Tree planting and tree improvement programs have become vital to forestry based industries in the United States, and we talk a lot about seedling quality because there is a feeling it could be improved. In the 1920s and 1930s when organic amendments were the major fertilizers and birds were an important factor in insect control, seedlings were hand lifted, graded, and the culls were left on the packing room floor. What we referred to as morphological grades, based on stem characteristics, proved quite satisfactory for assessing quality. Big seedlings proved to be the best for outplanting, and early grading standards reflected this fact (Wakeley 1954). Plantings were successful and demand for seedlings mushroomed. Forest tree nurseries could not meet the demand for large seedlings with existing bed space and technology.

Nursery technology was altered and improved. Inorganic fertilizers, new machines, more uniform irrigation systems, and chemical pest control were used to produce large numbers of large seedlings on relatively small areas of nursery bed. Unfortunately, these large seedlings did not survive and grow as well as seedlings of similar size did in the 1920s and 1930s. Gradually, morphological grading standards were discontinued and a new term - "physiological quality"—was introduced and readily accepted (Wakeley 1954). Nursery level tests were not available to judge physiological quality, which early researchers felt could only be judged on the basis of field performance.

With the southern pines, Wakeley (1954) suggested that significant changes in nursery management practices more than enviornmental conditions were directly responsible for the reduced effectiveness of morphological seedling grades as initially described. A combination of many complicating factors eventually resulted in the conclusion among researchers and other professional foresters that the physiological quality of a seedling was not necessarily reflected by the stem morphological grade.

For some years little emphasis was placed on what physiologically constituted high seedling quality. Most of the research emphasis for improving planting stock was directed toward the rapidly developing tree improvement programs. It was justifiably believed that breeding selected individuals would dramatically improve the growth potential of planting stock over that available from wild collections (Dorman 1976). It was also believed that the full benefits of our advancing nursery technology would be realized with genetically improved stock—that we would be improving the percentage of seedlings that met defined levels of performance (survival and growth) for a given species on a particular forest site (Duryea 1985).

After years of upgrading the seedling population and improving nursery management practices by clipping, shaking, spraying, dipping, fertilizing, and irrigating, has seedling quality been improved? Perhaps not! A recent survey of 53 nurseries by the Auburn University Southern Forest Nursery Management Cooperative indicates that we have serious problems (South and others 1985). Results showed that 83 percent of the nurseries were producing less than 20 percent grade 1 seedlings based upon 1920 standards and over a third of the seedlings from 66 percent of the nurseries were culls by the same standards. A loblolly pine seedling cull by these standards is one less than 5 inches tall and less than one-eighth inch in root-collar diameter!

Even more important, this survey also showed that in the past decade most nurseries use seed from improved sources for sowing. For whatever the reasons, stands established in recent years are not as productive as they were expected to be. To compensate for anticipated early losses, planting densities have been increased by 30 to 40 percent. Furthermore, progeny variability in performance trials in tree improvement programs continues to be a major concern voiced by the Southern Industrial Forestry Research Council (1984). In your home in the northern region, how many oak and walnut seedlings have you shipped in the past 20 years? How many of these individuals do you think are now dominant stems in successful plantations? Not very many, I'll bet. Have researchers missed something? Are we doing a bad planting job? Are foresters doing a poor job of matching species to site? Or are nurseries to blame for poor stock?

### *Lateral* **root** *development and seedling quality*

In 1974, at the U.S. Department of Agriculture, Forest Service in Athens, Georgia, I began my research to improve quality of sweetgum and other hardwood seedlings by manipulating vesicular-arbuscular mycorrhizal (VAM) fungi and soil fertility in nurseries. I was successful in improving what I thought to be seedling quality, but what has happened to other researchers happened to me. When outplanted, these quality seedlings did not compete any better than control seedlings grown in nursery beds devoid of mycorrhizal fungi. Over a period of years, several thousand sweetgum seedlings were excavated from different plantations to assess the mycorrhizal status of their roots and relate these data to survival and subsequent growth. We found (Kormanik 1985) that feeder roots of all seedlings, regardless of nursery treatment, were colonized by VAM fungi indigenous to the planting site within 6 to 8 weeks. Thus, mycorrhizal treatments in the nursery made little difference in the field.

During these studies, however, we noticed a wide range in seedling root development. We also saw that seedlings with many lateral roots were growing better in the field than those with fewer lateral roots.

We eventually tested scores of half-sib seedlots in nursery beds over a 5-year period. We found, based on the frequency distribution of permanent first-order lateral roots, that the seedling population was skewed to the left. What this means in practical terms is that from 40 to 60 percent of the seedlings from most mother trees tested had fewer than four permanent first-order lateral roots. These percentages were not significantly affected by fertility regimes in the nursery when the bed density was held near optimum. A minimum of four permanent first-order lateral roots was chosen as a cull criterion based upon stem and root development observed on several thousand seedlings.

What is a permanent first-order lateral root? I have arbitrarily defined a first-order lateral root with a diameter greater than or equal to 1mm as permanent and, thus, capable of influencing early seedling growth and development. I am not sure this diameter assumption is valid for all species at optimum bed densities, but it has afforded a constant parameter that can be refined as information is obtained from field trials.

Based upon the frequency distribution of seedlings from nursery trials and observations obtained from root excavations, I proposed that regardless of the phenotypic characteristics of a mother tree, associated progeny will exhibit a range in seedling development related to distribution of permanent first-order lateral roots, and that seedlings with fewer lateral roots will be less competitive in a forest environment. Initially, sweetgum was used as the test species in research on this concept, but we have since included walnut, ash, northern red oak, white oak, and loblolly and longleaf pines.

In nursery experiments with all these species, different combinations of root and top development have been observed. It is common to have big, vigorous seedling stems with few permanent first-order lateral roots. It is common to have small spindly tops with few permanent lateral roots. It is common (and desirable) to find healthy, vigorous stems with abundant first-order lateral roots. But I don't recall ever observing a seedling with high numbers of permanent lateral roots with a spindly, inferior stem.

Thus far, we have developed the equations that describe the frequency distribution of roots for several different species (Kormanik and Muse 1986). Within a species, fertilizer application increases seedling size but appears to have minimum effect upon number of first-order lateral roots. It is apparent that the number of first-order lateral roots among species is quite different. For example, a sweetgum seedling with six first-order lateral roots greater than 1 mm in diameter is likely to be competitive in a forest environment. With oak, however, a seedling with only six such lateral roots is a poor candidate for outplanting. Indeed, with red oak and black walnut, we consider a minimum of 10 lateral roots are needed and fewer than 20 percent of seedlings from some seedlots produced sufficient roots to be judged as being potentially competitive. While this cull rate appears to be excessively high, compare these percentages to survival and subsequent growth being reported in field plantings of some species. ***The problem may not be with your cultural practices in the* nursery or *in post-nursery handling. Many seedlings in a lot may be inherently inferior.*** This question has received little attention in our tree improvement programs and yet may partially account for the variability so commonly obtained in progeny tests.

So far we have only obtained field performance data for graded seedlings of sweetgum. Only recently other plantations have been installed with red oak and loblolly pine. First year field performance of sweetgum seedlings has been closely correlated with the number of first-order lateral roots before outplanting (Kormanik 1986). Growth of seedlings after 3 years also has been correlated with the same parameter.

### *Conclusion—In Retrospect*

At this point in my research, I am confident that the ability of a seedling to produce a large number of permanent first-order lateral roots is under considerable genetic control and that seedlings with many of such roots will be the most competitive in nature. The high percentage of seedlings that now die after outplanting may well indicate the importance of first-order lateral roots. I believe that field tests will validate lateral root numbers as a grading criterion. For sweetgum, we know that seed from a given mother tree can be collected in different years and grown at different fertility levels and that the frequency distribution of seedlings by lateral root numbers will be comparable. However, I feel that regardless of fertility level, some optimum bed density should be maintained for each species to obtain a balanced seedling that is capable of being competitive in a forest enviornment.

Assume, if you will, that the proportion of progeny with numerous permanent first-order lateral roots is under considerable genetic control. Simply growing bigger tops, as we have been asking our nurserymen to do, may be counterproductive. I do not mean that big seedlings are inferior—quite the contrary. In a uniform nursery bed lacking both soil and fertility gradients, the biggest seedlings will normally be the most competitive because they characteristically have the greater number of first-order lateral roots. However, significant nursery bed gradients are a fact of life and annual weather fluctuations can be counted on. These factors render stem morphological characteristics of questionable value for assessing seedling quality. With sweetgum, however, these factors do not appear to have a significant effect upon first-order lateral root expression.

With sweetgum we have ample evidence that numerous permanent first-order lateral roots improve initial survival during stress years and improve growth of outplanted seedlings in subsequent years (Kormanik 1986). At present, there is no valid method to evaluate seedling quality, but lateral root numbers may be an important ingredient for establishing such a method.

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