GRADING SEEDLINGS: IMPORTANCE AND LONG TERM IMPACT

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In addressing my subject, I want to emphasize "Long Term Impact". The long term impact of grading must be to improve yields of desired products or grading has no value.

Practically all agricultural commodities, from apples to zucchini squash, are sold by grade. As is proper, higher grade material commands a better price in the market place. Most graded agricultural products are used directly by the consumer, so the impact of grade is immediate. A small, badly bruised, malformed apple is not as desirable as a large, firm, well-developed one of the same variety. Producing a bushel of select 89-count apples costs significantly more than producing a bushel of 136-count orchard-run apples, but people are willing to pay more for select apples. In this example, the consumer can identify high quality apples and is willing to pay for them. Do foresters recognize high quality seedlings and, if so, are they willing to pay for them?

Nursery grown seedlings are a commodity but they are not the final product. The final product, the marketable stem, develops 20 years or more after the seedling leaves the nursery. The marketable stem (a stem's individual value or its marketable value per unit of land area) represents the long-term value that we hope to increase by grading seedlings.

Currently, there is no scientifically based procedure for identifying seedlings in tree nurseries that will be the most competitive trees in the forests. In my opinion, our failure to develop such a procedure has lead to the current practice of controlling seedling development to produce uniform-appearing individual seedlings. We fertilize, irrigate, and clip tops of seedlings to standardize their morphology. We want seedlings of a certain height and root collar diameter so we suppress developmental processes. Furthermore, our target size is the same for all nurseries and all parts of a given nursery. We know that edaphic conditions vary widely within as well as among nurseries but we ignore these variations in productive potential. We do everything we can to suppress variation in seedling characteristics, and we wonder why the grades assigned to seedlings are not good predictors of field performance.

Artificial regeneration with bare-root seedlings only began to be important since the end of World War II. Few second rotation plantations are available to determine if we have improved on the first, since most first-rotation plantations have not been harvested.

In this paper, I present my personal view of grading seedlings -- early work, present systems, and future possibilities. I do not address other problems associated with artificial regeneration, such as storage technique, planting logistics, the constantly changing environment, and variable edaphic conditions and I do not address quality requirements of particular species or regions. "Grading" and "quality" are used here in a broad, generic sense.

Perhaps this will emphasize my personal belief that while we all want quality seedlings, we may not know how to produce them operationally.

EARLY WORK.-- The need to judge a seedling's quality has been realized since the importance of artificial regeneration was recognized at the turn of the century. Initially, the guidelines for assessing seedling quality were simple--judge a seedling's quality by root development, not by stem characteristics (Tourney and Korstian 1954). The early emphasis was on producing stock with a large fibrous root system. The harsher the site, the greater the need for a large root system.

At the turn of the century nursery technology was primitive. Composted organic matter and manure were used to maintain soil fertility and birds were relied upon to reduce insect damage. Emphasis was placed on controlling soilborne or other disease organisms with proper sanitation because few effective pesticides were available. In most nurseries high seedbed density was maintained to compensate for anticipated losses. Individual seedling size was not important during the first year, because seedlings were placed in transplant beds to grow as 1-1 stock or left in the beds to be grown as 2-0 stock. On 2-0 stock, root pruning in the fall of the first growing season was recommended to encourage development of more fibrous roots during the second growing season. Root pruning was considered to be of equal importance for pine and hardwood seedlings.

Emphasis was placed on preparing seedlings to be competitive when outplanted, undersized seedlings were discarded. The effectiveness of these early nursery procedures is difficult to ascertain. Most plantings were done on an operational scale and there were very few research outplantings. Seedlings were frequently back-packed on horses or mules for several days before arrival at the planting site, and precise data on performance after planting were not collected. In spite of primitive nursery practices, however, many early plantations must have been successful because artificial regeneration came into favor in the United States as it had in Europe earlier.

The demand for seedlings soon outstripped the nursery supply of 1-1 and 2-0 stock. The solution in the south was to grow 1-0 stock. During these early stages of artificial regeneration, there was a gradual shift from concern about individual seedling characteristics, or a "seedling's quality", toward mass production of "quality seedlings". In the South, this change had major impact on survival and soon it was not unusual to have initial survival rates of 60 percent or less (Wakeley 1954).

Outplanting trials showed that large seedlings were usually more competitive than smaller ones. Initially, larger seedlings were obtained by maintaining them for longer periods in the nursery. Foresters began to request larger seedlings, and grading procedures were initiated in the nurseries to supply what was wanted.

PRESENT SYSTEMS.--Under the earliest nursery technology, the average seedling was small and the cull rate needed to obtain plantable seedlings was high (Wakeley 1954; Tourney and Korstian 1954). However, initial survival and growth of graded seedlings were outstanding in comparison to results obtained with bed-run seedlings. As a result, minimum heights and root collar diameters were adopted for many important species and the grading system based on these measurements worked. Other important morphological traits relating to stems and roots were ignored, and the importance of specific height and root collar diameters for many species became firmly entrenched.

But then, something began to change that affected seedling performance in the field. In the late 1930's, modern agronomic practices were introduced into forest nurseries. Inorganic fertilizers, pesticides, and complex irrigation systems increased the average size of nursery seedlings. It became possible to force seedling growth to meet the previously established standards. Wakeley (1954) was one of the leaders in establishing early standards for many of the southern pines. Results from his early research in Louisiana on plantation performance of stock based on "morphological grades" served as a catalyst for the acceptance of artificial regeneration. He was among the first forest scientists to advocate and implement modern agronomic practices in forest tree nurseries. Most significant of the changes were reductions in seedling bed densities, enhancement of soil fertility, and installation of modern irrigation systems. With these changes, most of the seedlings produced met previously established morphological grade standards. Unfortunately, field performance of this new generation of seedlings was variable and didn't compare favorably with results obtained in earlier trials. Comparable unfavorable results were reported from many different sources and the validity of morphological grades for any species was questioned (Wakeley 1954).

Eventually, Wakeley (1954) concluded that improvements in nursery technology were affecting the "physiological quality" of seedlings as well as the applicability of previously established morphological grades. He questioned the continued use of morphological grades, and longed for an improved grading system: "Physiological qualities cannot be determined by ocular inspection. No means, such as chemical testing of the foliage, has yet been developed for recognizing various physiological qualities of southern pines; the only way so far discovered for determining them is to plant the seedlings and observe their survival and growth." In my opinion, this observation still holds true **in** 1990.

During the last decade we began questioning competitive ability of seedlings in nurseries. More and more nurserymen and foresters were questioning the relative values of large and small seedlings. In a "good" year, all seedlings were large enough to exceed minimum size for outplanting. In a "bad" year, a high percentage of the crop barely met minimum standards, and even the larger seedlings weren't much larger than medium grade seedlings produced in a good year. Field results, however, revealed that seedlings produced in a good year seldom outperformed those produced in a year when the cull percentage was higher. Grading was finally modified to cull only damaged or diseased seedlings.

The appearance of tree improvement programs further reduced the desire to grade seedlings. Genetically improved seeds from these programs cost a great deal, and people didn't want to waste seedlings by grading and culling. Heavy applications of fertilizer and efficient irrigation systems made it possible to grow seedlings much larger than desired for efficient planting. To offset rapid growth, top-clipping of southern pines several times a year came into vogue (Southern Pine Nursery Handbook 1984). Clipping the largest and most competitive seedlings released smaller, less competitive seedlings, which, for a period of time, outgrew the seedlings that had been clipped. Seedlings with more uniform stem characteristics were produced and were sold by weight instead of count or grade. Cull percentages of less than 5 percent were expected as a result of these nursery improvements (Southern Pine Nursery Handbook 1984).

Plantation performance with clipped seedlings was poorer than expected, and it became common practice to plant 750 or 850 seedlings per acre to compensate for poor individual performance and/or high mortality. Higher plantation density resulted in increased planting and maintenance costs and, coupled with less than expected yield, cast a shadow over artificial regeneration. The demand for graded seedlings that would be competitive in the forest environment was again heard. Minimum root collar diameters, and height nearly identical to criteria that had failed in the late 1930's, were proposed (Southern Pine Nursery Handbook 1984).

Meanwhile in the late 1970's and early 1980's, at the Institute for Mycorrhizal Research and Development we and our cooperators found that many hardwood seedlings could be grown to acceptable sizes at lower than standard soil nursery fertility levels if the seedling roots were adequately colonized by vesicular-arbuscular mycorrhizal (VAM) fungi. Research also showed that at very high soil phosphorus fertility levels, in the absence of VAM colonization, seedlings were larger and more uniform than those grown at lower soil fertility levels. Much of the initial research was with sweetgum. From early field trials, we concluded that we could not successfully grade sweetgum seedlings by using percentage of roots colonized by VAM or by establishing morphological grades based upon stem characteristics. Finally, after excavating thousands of sweetgum seedlings in nurseries and young plantations over several years, it became apparent that individuals with many first-order lateral roots (FOLR) were consistently outperforming those with fewer FOLR. It was clear that more lateral roots supported more feeder roots susceptible to mycorrhizal fungi in the field, which in turn could maintain a larger stem.

Back in the nursery, we examined a dozen commercially important forest tree species and clearly established that the most competitive seedlings in the nursery always had the highest number of FOLR. Soil and fertility practices, as well as irrigation, could significantly affect seedling size, but the least competitive seedlings for a given set of nursery conditions were always those with the fewest roots. I often referred to these non-competitive seedlings as "genetic junk". They were always present--even in the best families. The initial work with sweetgum indicated that early field performance of seedlings, particularly their competitive ability, could be predicted based on lateral root numbers when they were lifted in the nursery (Kormanik 1986). This finding indicates that an empirical grading system might be developed based upon biological principles rather than current nursery management technology.

FUTURE.--If a seedling's relative competitive ability in a nursery under existing management practices is a fair assessment of its future potential in a forest environment, the future for grading seedlings appears promising. If early yields from graded sweetgum seedlings reflect the responses of other tree species, grading is going to be very important for most species. These last two qualifying statements begin with an "if." The "if" is not used because of biological reservations on my part, but because I believe we must develop a workable empirical scale for grading. Much research is needed and considerable time will pass before we know if a useful, empirical grading system can be developed. We will only know if the scale is correct when yield data are obtained.

We can expect considerable resistance to any grading procedure that discards large numbers of seedlings. And that is understandable. Nurserymen have grown accustomed to selling 95 percent of their product, and selling less is not going to be accepted easily.

If grading is to have a future and long-term impact, we must recognize that individual nurseries and, indeed, separate sections of the same nursery, are unique entitities. A single fertility or irrigation schedule may not be proper for an entire operation. All parts of a nursery may not be suitable for a given species. Bed density must be controlled. We must realize that each square foot of soil can produce only so many seedlings of desired quality. If we must cull 30 percent of the seedlings, we should not increase density by 30 percent to obtain the needed planting stock. It won't work. In most cases, hardwood densities should not exceed 6/ft in any nursery in any region of the U.S.

For grading to have an impact, each nursery supervisor must determine procedures for producing seedlings required for successful reforestation in his specific region. We must set new standards and not accept questionable ones simply because they are traditional. It must then be determined what nursery practices are required to obtain these seedlings. In other words, we must determine what management input is needed for a given seedling output.

I question that any nursery operation is presently under-fertilized or under-irrigated, and I would speculate that 80 percent are applying more fertilizer and water than needed to produce high quality planting stock. Furthermore, I suspect that timing of applications is as important or more important than the total amount applied.

In a recent wide-scale nursery testing program Marx et al. 1984 concluded somewhat facetiously that nutrient levels were so high in some nurseries that it would be better to mine the soil for minerals than to grow seedlings. While this comment was offered in jest, its message is important: We need to be concerned about the adverse affect of excessive fertilization on seedling quality. More concern should be given to balancing elements in nursery soils and timing their application. Irrigation practices need to be carefully planned and executed because water drastically affects soil nutrient balances and seedling development. Its effect on root/shoot ratios is dramatic. I am not aware of a single forest tree nursery that has obtained a moisture depletion curve to help regulate the irrigation schedule. Often sandy soils and or clay soils are watered on comparable schedules.

We have scientific evidence that numbers of FOLR in offsprings of most of our important forest tree species are under strong genetic control. Seedlings with the greatest FOLR numbers are always the most competitive in the nursery. Thus, we may now have a biological basis for out empirical system. Most of these FOLR data have been produced in the past 5 to 10 years in experimental nurseries. Many of you in the Nursery Hardwood Cooperative have started to put research into practice.

It seems clear that the successful development and implementation of grading procedures depends on the willingness of organizations to change nursery procedures that prevent us from identifying a seedling's quality. Many are beginning to realize that standard grades will be impossible without first standardizing nutrient and water availability in nurseries. In most cases, it would take 3 to 5 years of soil monitoring to obtain and maintain a reasonable baseline of soil fertility for a given nursery. From this baseline our management practices can be adjusted up or down for a given species. It will work, and management decisions do change. Recently, the State of Georgia began to monitor soil fertility levels, irrigation schedules, and seedbed densities in selected portions of some nurseries. As expected, soil fertility levels proved to be very high (Marx et al. 1984). For 3 years, individual areas in Georgia nurseries growing loblolly pine seedlings (*Pinus taeda* L.) received little or no nutrients except for light applications of nitrogen or other elements needing slight adjustments. Even after this period of time, phosphorus and most other essential elements exceeded levels required for optimum pine seedling production. Each subsequent crop improved as nutrients were balanced. After the third year, seedlings could be grown to desirable sizes without top clipping to control excessive stem elongation. Elimination of top clipping appears to reduce grading time, since noncompetitive seedlings with few roots seldom grow into the seedling crown canopy. Graders were able to process seedlings more rapidly because the slow-growing, inferior trees--genetic junk--were conspicuous.

CONCLUSION.--There are sound biological reasons to believe that valid empirical grading procedures can be developed for all important forest tree species. Development of this technology does not depend entirely on those of us in research. Forest-based organizations must be willing to alter nursery procedures to put seedling production on a sound scientific basis. We must forget about a "rule of thumb" for grading that is applicable to all species in all nurseries. A valid grading system that will have an impact in the future depends on standardizing and controlling soil fertility, bed density, and irrigation practices. Without these constraints, the future holds no more promise for grading seedlings than the past.

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