Visual Grading and Quality of 1-0 Northern Red Oak Seedlings

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ABSTRACT: *Past research has used detailed measurements of various growth characteristics to determine seedling grades and quality of northern red oak nursery stock. This study evaluates the effectiveness of a visual grading process, similar to those found in commercial nursery operations, to distinguish high quality seedlings. Northern red oak* (Quercus rubra L.) *seedlings were grown for 1 yr at two state nurseries and visually separated into three grades (cull, good, or premium) according to root and shoot characteristics. Approximately 64% of the seedlings grown at each nursery were judged to be of unacceptable size for successful field regeneration. Number of first-order lateral roots (FOLR), height, and root collar diameter (RCD) were measured for seedlings in the good and premium grades. Premium grade seedlings were significantly larger than the good grade seedlings for both nurseries. Phenotypic correlations of growth traits were strongest between number of FOLR and RCD. The results demonstrate that high quality nursery stock can be visually selected into two distinguishable grades. South. J. Appl. For. 24(2):93–97.*

Many eastern North American stands currently dominated by oak (*Quercus* spp.) contain high proportions of nonoak species following natural mortality or harvesting (Lorimer 1993). This is particularly true on high quality mesic sites (site index ≥ 21.3 m+), where competition is intense (cf. Johnson 1993, Trimble 1973). Even with overstory removal, the smaller, slow-growing oak regeneration cannot compete with more vigorous species such as red maple (*Acer rubrum* L.) or yellow-poplar (*Liriodendron tulipifera* L.) (Beck and Hooper 1986, Loftis 1983, Sander 1972). Historically, frequent natural and Native American-set fires created conditions favorable for regeneration of oak species (Abrams 1992, Buckner and Turrill 1999). Additional disturbances by settlers and the disappearance of the American chestnut (*Castanea dentata* [Marsh.] Borkh) maintained a significant oak component throughout much of eastern North American upland forests (Abrams 1992, Lorimer 1985). Fire reduction and suppression during this century has allowed other species that are less fire-resistant to achieve dominance in stands which previously contained a high proportion of oak species (Watt et al. 1992).

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Artificial regeneration of different oak species has been attempted to supplement natural regeneration on high quality sites. Generally these attempts have had limited success, as the oak seedlings were overtopped by faster growing vegetation. The resulting decrease in light caused suppression and senescence (Johnson 1976, McGee and Loftis 1986, Russell 1973). Planting failures can be partially attributed to the failure of commercial forest tree nurseries to produce and grade seedlings to provide high quality nursery stock. Nurseries typically establish their own procedures for growing oak seedlings (Kormanik and Ruehle 1987), directed toward attaining a uniform size to facilitate handling, shipping, and planting procedures (Johnson 1981, Kormanik and Ruehle 1987), and grading of hardwood seedlings is not a common nursery practice.

Previous studies have been conducted to determine relationships between seedling size at planting and subsequent growth in the field. Northern red oak (*Q. rubra* L.) seedlings with taller stems at planting have been shown to have better height growth over time than smaller nursery seedlings (Foster and Farmer 1970, Johnson 1976, Zaczek et al. 1997). Nursery seedlings with the highest numbers of first-order lateral roots (FOLR) generally were tallest after one growing season in the nursery (Kormanik et al. 1994a, Ruehle and Kormanik 1986) and after 3 to 7 yr in the field (Kormanik et al. 1995, Teclaw and Isebrands 1993, Thompson and Schultz 1995). A number of the above studies measured seedlings after lifting, separated them into size classes, and determined quality of each class based on field performance (Kormanik et al. 1995, Teclaw and Isebrands 1993, Thompson and Schultz 1995). Grading seedlings in a commercial nursery operation, however, is generally not based on precise measurements, but on visual assessment of seedling size by relatively unskilled nursery workers. The ability to identify quality seedlings through visual grading has not been well documented. This study was designed to resemble the visual grading processes used in commercial nursery operations. Specific objectives were: (1) to examine the quality of northern red oak nursery stock that was visually selected for planting based on a combination of seedling attributes, and (2) to examine correlations among growth characteristics of visually graded seedlings.

Materials and Methods

Acorn Collection and Sowing

A northern red oak progeny test on the Watauga Ranger District of the Cherokee National Forest was thinned in 1987 to create a seedling seed orchard (LaFarge and Lewis 1987). Acorns were collected from individual trees in the seed orchard in Fall 1995 for use in reforestation. The collected acorns were placed in water to separate sinking from floating acorns (Olson 1974). Only sinking acorns were distributed for propagation.

The acorns were bulked for sowing at two state nurseries: the Flint River Nursery operated by the Georgia Forestry Commission in Montezuma, Georgia, and the Ralph Edwards State Nursery operated by the North Carolina Division of Forest Resources in Morganton, North Carolina. The seed mix was different for each state nursery, reflecting the environmental differences of probable planting sites (Lay 1999). The North Carolina (NC) nursery had more families from the Appalachian Mountain region, while the Georgia (GA) nursery had more families from the relatively warmer western Tennessee Valley region. There was a 25 to 30% overlap of genetic material between the two nurseries.

Nursery Practices

The acorns were sown in the late fall of 1995 by machine to achieve a desired density of 65/m seedlings. Later density checks confirmed that density was at 65/m seedlings for the GA nursery and 84/m seedlings for the NC nursery.

Fertilization and irrigation regimes for the GA nursery were developed by the USDA Forest Service's Institute for Tree Root Biology as delineated in Kormanik et al. (1994b). Ammonium nitrate was applied every 10 to 12 days at a rate of 8.3 kg/ha in May, increasing over the growing season to a rate of 27.6 kg/ha by October. In late July, one application of K-Mag was applied at a rate of 41.1 kg/ha. The NC nursery applied similar rates of ammonium nitrate but adjusted applications to their shorter growing season. In addition, the NC seedlings received two applications of diammonium phosphate at a rate of 27.6 kg/ha.

At both nurseries, a Fobro™ machine lifter was used to undercut (30 cm) and lift seedlings for grading in January of 1997. The trees were bundled in groups of approximately 100 seedlings and placed in cold storage until grading.

Visual Grading

Approximately 1,000 seedlings were obtained from each nursery. Six people constituted the grading crew; one person had previous experience in phenotypic grading of oak seedlings, and another person had experience in measuring characteristics, i.e., number of FOLR, and four people had no experience in handling nursery seedlings. The seedlings from each nursery were taken from the storage bags, and overall nursery population was visually assessed according to the following parameters: FOLR number, tap root size, root collar diameter (RCD), and stem height. A few representative seedlings from each nursery that appeared to be of average size, considering the aforementioned characteristics, were chosen as the minimum size criteria for grading. These representative seedlings remained available to the graders as visual references during the entire grading process.

The grading crew was instructed to select 360 seedlings from each nursery that appeared to be equal to or above the minimum size criteria by considering the following seedling traits with equal importance: FOLR number, tap root size, RCD, and stem height. This seedling number was partially determined by the size of the site for an experimental planting, and previous research has demonstrated that approximately 40% of northern red oak nursery stock will have above-average growth, and therefore have sufficient quality for planting (Kormanik and Ruehle 1987).

The grading crew initially selected the largest seedlings from each nursery population. After approximately 15% to 20% of the largest seedlings from each nursery were selected, a relatively sharp drop in seedling quality was observed. The remaining 15% to 20% of the seedlings from each nursery were graded as acceptable for planting, but appeared to be comparatively lower in quality than the seedlings initially selected. Based on these observations, a decision was made to distinguish two grades of plantable seedlings, "good" and "premium." The premium grade seedlings were the largest in overall seedling size and generally had more numbers of FOLR than "good" seedlings. The seedlings graded as "good" were relatively reduced in size and number of FOLR to the "premium" grade seedlings, but above-average in relation to the representative seedlings from each nursery. The remaining seedlings generally were smaller in overall size, had fewer numbers of FOLR, and/or exhibited undesirable features, e.g., forked stem, broken top, or deformed tap root, compared to the "premium" or "good" grade seedlings. As the 360 seedlings from the "premium" and "good" grades were being counted out for the experimental planting, the "good" grade seedlings were further refined if the number of seedlings in both grades combined exceeded 360, i.e., the most marginal in quality of the "good" grade seedlings were culled. From each nursery, approximately 18% of the seedlings were graded as premium, 18% were graded as good, and the remaining 64% were culled.

Seedling Measurements

After grading, the number of FOLR, RCD, and height were measured and recorded for each seedling in the premium and good grades. A FOLR was defined as a suberized lateral root stemming from the main taproot that is at least 1

Table 1. Means, ranges, and standard deviations (SD) for first-order lateral roots (FOLR), height, and root collar diameter (RCD) for good and premium grade northern red oak seedlings grown at the Flint River Nursery, Montezuma, Georgia (GA) and the Ralph Edwards State Nursery, Morganton, North Carolina (NC)

	No. of FOLR			Height (cm)			RCD (mm)		
Nursery/grade	Mean	Range	SD	Mean	Range	SD	Mean	Range	SD
GA good	13a	2–29	4.6	71.5a*	37.5–118.5	14.2	8.5a	5.8–12.0	1.2
GA premium	18b	7–35	4.7	85.0b	52.0–130.0	17.1	10.6b	7.1–19.4	1.6
NC good	7a	0–24	4.0	64.6a	31.0–104.0	15.3	7.6a	5.1–12.1	1.1
NC premium	13b	1–30	4.6	89.0b	38.5–148.0	22.8	9.6b	7.1–14.7	1.3

* Means followed by the same letter are not different within the same nursery and trait ($\alpha < 0.05$)

mm in size (Kormanik et al. 1990). The RCD was measured 2.54 cm above the root collar using a digital caliper. The height was measured to the nearest 0.5 cm from the RCD to the top of the terminal bud.

Statistical Analyses

The data were analyzed using statistical packages available in SAS version 6.11 (SAS 1996). Means of FOLR number, height, and RCD for seedlings in the premium and good grades were calculated for each nursery. The PROC GLM procedure was used to determine significant differences between seedling grades for each nursery. In addition, PROC CORR was used to calculate Pearson correlation coefficients among growth characteristics for seedlings in the premium and good grades. An error level of $\alpha = 0.05$ was chosen to indicate significant differences in all statistical procedures.

Results

The premium grade seedlings from both nurseries had significantly more FOLR, taller heights, and bigger RCDs than the good grade seedlings (Table 1). For the GA premium and good grade seedlings, the strongest correlations were between FOLR and RCD ($r = 0.31$ and 0.52, respectively) (Table 2). The strongest correlations for the NC good seedlings were between FOLR and RCD ($r = 0.45$) and between height and RCD ($r = 0.45$). The strongest correlation for the NC premium seedlings were between FOLR and RCD ($r = 0.46$) Only the NC premium grade seedlings had a significantly positive correlation between FOLR and height ($r = 0.29$)

Discussion

Overall Seedling Quality

The selected seedlings generally met current recommendations for FOLR numbers, size of RCD and stem height to be considered acceptable for field planting (Johnson 1981, Kormanik et al. 1994a, Thompson and Schultz 1989). Although the number of seedlings selected for each grade was influenced *a priori* by the size of the planting site, few additional seedlings, i.e., less than 5% from each nursery, would have been considered acceptable for the good grade. The resulting cull proportion was relatively high (64%), but corresponds to other nursery studies that found between 40 to 60% of nursery stock was of an unacceptable size for planting (Kormanik and Ruehle 1987, Kormanik et al. 1994a, Stroempl 1985).

Differences Between Good and Premium Grades

This study demonstrated that plantable stock can be further subdivided into two distinctive grades (good and premium) by visual grading. Although both grades generally met recommendations for identifying high quality nursery stock (Johnson 1981, Kormanik et al. 1994a, Thompson and Schultz 1989), the premium grade seedlings grew larger in the nursery and may outperform the good grade seedlings when planted in the field (Kormanik et al. 1995). A study on a high quality site in North Carolina used seedlings that were divided into three grades: good, medium, or poor, based on numbers of FOLR. After five growing seasons, 52% of the seedlings in the good grade (>11 FOLR) were classified as free of competition, followed by 28% and 6% of the seedlings in the medium (7–11 FOLR) and poor (< 7 FOLR) grades, respectively. The results of Kormanik et al. (1995) indicate that oak seedlings in the highest quality grade may outperform seedlings in the next lowest grade, while seedlings from both grades had relatively successful field performance. Depending on the overall size of the nursery stock, two distinct grades of plantable seedlings allows for the option of planting the highest quality seedlings (premium grade) on sites with the greatest amount of competition.

Correlations Between Growth Characteristics

The stronger correlation ($r = 0.68$) between FOLR and height that Ruehle and Kormanik (1986) found for a population of approximately 400 northern red oak seed-

Table 2. Correlation among growth characteristics for good and premium grade northern red oak seedlings grown at the Flint River Nursery, Montezuma, Georgia (GA) and the Ralph Edwards State Nursery, Morganton, North Carolina (NC).

Nursery and grade	FOLR–RCD	FOLR–Height	Height–RCD
GA good	0.52*	–0.01	0.17
GA premium	0.31*	–0.03	0.04
NC good	0.45*	0.01	0.45*
NC premium	0.46*	0.29*	0.54*

* Correlation value is significant at $\alpha < 0.05$

lings was not as evident for seedlings from either nursery in this study. The weaker correlation values in this study are largely attributed to the exclusion of the cull seedlings from the correlation calculations. Ruehle and Kormanik's (1986) correlation value was not influenced by seedling grade. A contributing factor is the manner of seedling selection used in this study, which was similar to grading operations performed by unskilled nursery workers. For example, seedlings with few FOLR, but large heights were selected as well as seedlings with relatively short heights and large FOLR numbers. In addition, the slightly higher sowing density at the NC nursery may have reduced FOLR to height correlations for that nursery.

The positive correlations between RCD and FOLR (Table 2) and between RCD and height (NC seedlings only) demonstrates that RCD may be a good indicator of root mass (Johnson 1989) and height (Olson and Hooper 1972). Root collar diameter, however, was not positively related to height growth for the Georgia seedlings and RCD correlations with FOLR were not perfect. Root collar diameter, therefore, should be used in conjunction with other seedling characteristics when visually separating good from premium grades.

Application to Nursery Operation and Field Plantings

Nurseries differ in length of growing season, precipitation, and temperature, and typically implement different growing regimes for northern red oak. Size and quality of nursery stock will probably vary among nurseries, and therefore visual grading should be relative to the overall seedling quality at each nursery. Although the GA seedlings had overall larger root systems and diameters than the NC seedlings, both nurseries had approximately the same percentage of cull, good, and premium grade seedlings. In addition, both nurseries produced relatively large nursery stock, allowing for easy identification of the most competitive seedlings during grading.

In an unrelated study, seedlings at a Tennessee nursery were grown in 1996 with inadequate fertilization and irrigation procedures, and then visually graded for planting (Lay, unpublished data). The seedlings generally were small and poorly developed, and visual grading was more difficult when compared with grading the larger seedlings from the GA and NC nurseries. The relatively poorer growth of these trees resulted in only two grades (cull or plantable) to be distinguished, and a premium grade could not be identified. Nursery practices should be adjusted to allow full development of the seedlings for nursery personnel to properly grade seedlings (Kormanik et al. 1994a, Kormanik et al. 1994b, Kormanik and Ruehle 1987).

The study demonstrates that the largest seedlings can be easily distinguished after briefing nursery workers on the important characteristics to consider when grading and showing representative seedlings exhibiting minimum size standards. Separating out the highest quality seedlings (premium grade) gives landowners the ability to plant the best quality seedlings on the most productive sites. More research is needed, however, to determine the ability of visually graded northern red oak nursery stock to survive and compete successfully on a variety of sites under differing management practices. Evaluation of survival and growth in the outplanting from this study and other red oak progeny tests established in 1995 (Lay et al. 1997) should contribute information on the importance of visual grading to the artificial regeneration of oaks.

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