FIELD PERFORMANCE OF HIGH-QUALITY AND STANDARD NORTHERN RED OAK SEEDLINGS IN TENNESSEE

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Abstract--First-year performance of high-quality (HQ), high- quality cull (HQC) and standard (ST) northern red oak (*Quercus rubra*) nursery seedlings was compared in a study established in a recent clearcut in mid-March, 2000. Objectives were to test effects of 1) seedling type, 2) planting treatment, and 3) control of competitors on the growth, browsing, and survival of planted seedlings. HQ, HQC, and ST northern red oak nursery seedlings averaging 109, 58, and 23 centimeters in height, respectively, were planted in three planting treatments: 1) row planting, 2) random spacing, and 3) inter-planting with loblolly pine (*Pinus* taeda). Three of 6 replicates for each planting treatment were chosen at random to receive competition control. Analyses within seedling types indicated no statistically significant differences between planting and competition control treatments in the first year. Differences between seedling types were much stronger. Height growth of HQ and HQC seedlings was significantly greater than that of ST seedlings. However, the incidence of browsing of HQ and HQC seedlings was also significantly greater than that of ST seedlings. Mortality of ST seedlings was significantly greater than HQC seedlings, but not significantly greater than HQ seedlings. It remains to be seen whether HQ seedlings will maintain their advantage over HQC and ST seedlings with continued browsing, and whether differences between planting and competition control treatments will strengthen as vegetation development and browsing continues.

INTRODUCTION

Artificial regeneration of oak can alleviate several problems during the early stages of regeneration such as insufficient seed sources, acorn predation, poor germination conditions, and heavy competition. Artificial regeneration with HQ seedlings can also be used to improve the quality of oak in stands where various forms of mismanagement have taken place. HQ or "super" oak nursery seedlings represent a promising alternative to ST seedlings for artificial regeneration. Seedling characteristics such as the number of coarse lateral roots and the overall size of shoots and roots are thought to be correlated with increased survival and competitive ability of oak seedlings after outplanting (Kormanik and others 1995, Kormanik and others 1997, Zaczek and others 1997). Relationships between nursery practices and these characteristics have been investigated, and protocols have been developed for producing seedlings that meet desired criteria (Kormanik and others 1994). Further, it has been demonstrated that high- and low-quality seedling grades can be distinguished visually prior to planting (Clark and others 2000). While progress has been made in defining and producing HQ oak planting stock, studies addressing the performance of different grades of seedlings are limited in number(for example Gordon and others 1995, Gottschalk and Marquis 1983, Zaczek and others 1997). Fewer still (for example Kormanik and others 1997) have documented outplanting results for HQ oak seedlings produced by the protocol developed by Kormanik and others (1994).

Potential limitations to the performance of HQ seedlings after outplanting are heavy competition with other woody vegetation and white tailed deer (*Odocoileus virginianus*) browsing. Intense competition with hardwood stump sprouts and fast-growing species arising from seed may affect the development of HQ oak seedlings, despite their large size and competitive potential (Kormanik and others 1997). Herbivory may compromise the competitive ability of any plant species (Louda and others 1990) and deer browsing can combine with heavy competition to have a synergistic, negative effect on survival. Experiences with outplanting oak nursery seedlings in Tennessee and several other regions indicate that deer have a high affinity for nursery seedlings (Buckley and others 1998, Gordon and others 1995, Kormanik and others 1995, Teclaw and Isebrands 1991). Fertilization of nursery stock may make freshly planted nursery seedlings more nutritious than the surrounding native vegetation. Controlling deer browsing is essential to establishing HQ oak plantings in areas with high deer populations. Repellants, tree shelters, and fencing methods have been developed for guarding against deer damage (Craven and Hygnstrom 1994, Nolte and Otto 1996). Unfortunately, the effectiveness of some repellants appears to depend on what other forage is available, and the costs of tree shelters and fencing can be prohibitive.

An alternative means of reducing deer browsing may be modified planting techniques that take advantage of

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Citation *for proceedings:* Outcalt, Kenneth W., ed. 2002. Proceedings of the eleventh biennial southern silvicultural research conference Gen. Tech. Rep. SRS-48. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 622 p.

relationships between deer foraging behavior, the spatial arrangement of seedlings, and structure formed by the surrounding vegetation. In prior studies conducted in Michigan, differences in the incidence of browsing of planted oak seedlings were documented over short distances with differences in vegetation structure (Buckley and others 1998). Browse damage of planted seedlings was far less frequent and intense in rows where red pine (*Pinus resinosa*) seedlings were inter-planted with northern red oak seedlings, and wherever competing vegetation partially or completely obscured a planted seedling. These observations warrant further investigation, and indicate that modification of the spatial and structural aspects of standard planting techniques may help reduce browsing losses.

OBJECTIVES

Objectives of this study were to: 1) Compare survival, growth, and browsing of 1-O HQ northern red oak seed-ling&l -0 HQC seedlings, and 1-O ST seedlings planted in a recent clearcut in East Tennessee, 2) Investigate effects of controlling woody competitors on survival, growth, and browsing of each type of seedling, and 3) Test the viability of reducing deer browsing of planted seedlings by planting in a random pattern as opposed to a row pattern, and by inter-planting oak and loblolly pine.

METHODS

This study was established in a one-year old clearcut on the University of Tennessee Forestry Experiment Station, located near Oak Ridge in the Ridge and Valley Province of East Tennessee. All plots were located on the upper half of a north-facing slope. Site productivity was intermediate, and northern red oak formed a component of the stand prior to harvesting. Plots were laid out in an east-west line parallel to the edge of the adjoining unharvested stand (located up slope) to minimize bias in the entry of plots by deer, and spatial relationships with surrounding forest and landform features (figure 1). A 12.2 meter buffer zone was maintained between the unharvested stand edge and the upper margin of each plot (figure 1). A 7.3 meter buffer zone was maintained between all plots (figure 1.).

Six treatment combinations consisting of competition control or no competition control combined with a row planting pattern, a random planting pattern, and a row planting pattern where oak seedlings were inter-planted with loblolly pine were assigned at random to 3.7 x 16.5 meter plots (figure 1). Each treatment combination was replicated 3 times for a total of 18 3.7 x 16.5 meter plots in the study. A deer exclosure containing a row and an inter-planted plot was installed on the east end of the clearcut (figure 1) to allow comparisons of planted oak performance and vegetation development without any browsing.

Row plots contained 30 northern red oak seedlings planted in 3 rows on a 1.8 m spacing. Random plots contained 30 oak seedlings planted in a random pattern. Inter-planted plots contained 30 oak seedlings in 3 rows on a 1.8 meter spacing, inter-planted with loblolly pine seedlings. In the inter-planted rows, a 1-O loblolly pine seedling was planted on both sides of each oak, 0.5 meter from the oak seedling stem (figure 1). All plots received 15 HQ northern red oak seedlings, 5 HQC seedlings, and 10 ST northern red oak seedlings. All seedling types were bare-root, 1-O seed-lings. HQ northern red oak seedlings from 5 genetic families were assigned to planting locations within plots in incomplete blocks to address potential interactions between slope position and performance of each family. HQC and ST seedlings were assigned to remaining locations at random. Both HQ and HQC seedlings were raised in the Flint River Nursery operated by the Georgia Forestry Commission in Montezuma, GA according to a protocol developed for producing HQ oak seedlings (Kormanik and others 1994). HQ and HQC seedlings were distinguished based on the number of first-order

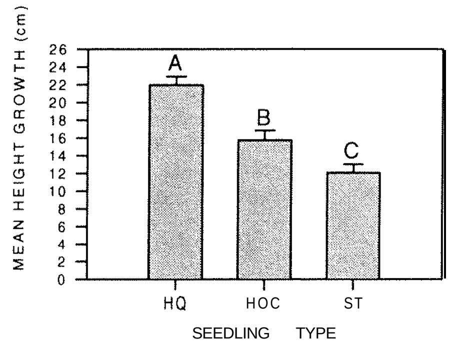

Figure 2-Mean 2000 height growth by seedling type. Means with different letters are significantly different based on ANOVA and Tukey's HSD at the α = 0.05 level. Error bars represent 1 S.E.

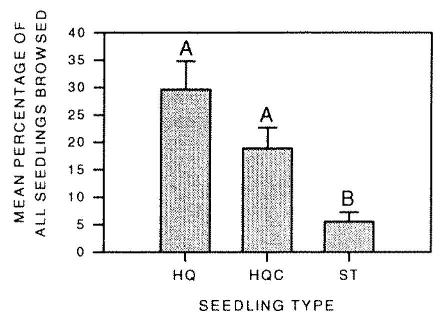

Figure 3-Mean percentage of seedlings with any type of browse damage in 2000 by seedling type. indication of signifi-cant differences, tests, and error bars as in figure 2.

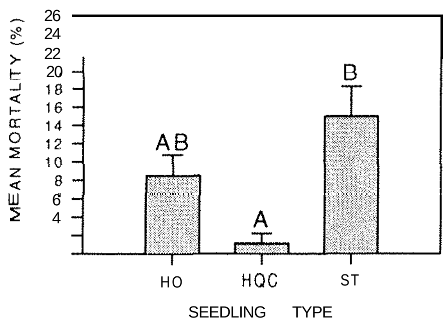

Figure 4-Mean 2000 percent mortality by seedling type. Indication of significant differences, tests, and error bars as in figure 2.

lateral roots, root collar diameter, and height (Clark and others 2000). ST seedlings were nursery-run seedlings obtained from a Tennessee nursery. Mean heights of HQ seedlings, HQC seedlings, and ST seedlings at the time of planting were 109, 58, and 23 centimeters, respectively.

Planting was completed March 20-22, 2000. Northern red oak seedlings were planted with a 20 centimeter diameter auger mounted on a 4-wheel drive tractor. Loblolly pine seedlings were planted with planting bars. No supplemental watering was used.

Woody and herbaceous competitors of oak seedlings were sprayed with glyphosate August 1 O-l 5, 2000 in all competition control plots. Oak seedlings were shielded during spraying to reduce potential damage due to drifting spray. Competition control treatments will be repeated in subsequent growing seasons.

Initial height of all planted oaks was measured between the soil surface and the tip of the terminal bud on the dominant leader. Height growth for the first growing season was determined by remeasuring heights in the same manner as described above on October IO, 2000. Seedlings were tallied for bud break and development of the first growth flush on May 5, 2000 and again on June 9, 2000. Damage due to deer browsing was recorded on June 9, July 21, and October 19, 2000. Both the presence of browsing and the type of browsing (terminal leader, lateral branch, or a combination) were documented. Mortality was recorded on the same dates as browsing. Seedlings were considered dead when shoots were completely missing, or when no live buds or green inner bark could be found on stems and at the root collar.

Preliminary analyses run within seedling types indicated no statistically significant effects of planting and competition control treatments at the $\alpha = 0.05$ level. Thus, differences between seedling types in growth, browsing, and mortality were analyzed through ANOVA and Tukey's HSD using data pooled over planting and competition control treatments.

RESULTS

Although planting and competition control treatment effects were not statistically significant, there was a trend toward slightly greater growth of HQ seedlings in plots receiving competition control. There'were also trends toward a slightly lower incidence of browsing of HQ and HQC seedlings in inter-planted plots than in row and random plots, and toward greater mortality of seedlings with competition control than without.

Much stronger differences occurred between seedling types in phenology, growth, browsing, and mortality. HQ seedlings flushed later than HQC and ST seedlings. Only 62 percent of HQ seedlings had broken bud by May 5, 2000, compared with 98 and 97 percent of HQC and ST seedlings, respectively. Mean height growth of HQ seedlings was significantly greater than that of HQC and ST seedlings (figure 2). Mean height growth of HQC seedlings was significantly greater than that of ST seedlings, but significantly less than that of HQ seedlings (figure 2).

The mean percentages of HQ and HQC seedlings that had any degree of deer damage were significantly greater than the mean percentage of ST seedlings showing browse damage (figure 3). As was the case for height growth, browsing of HQC seedlings was intermediate between browsing of HQ and ST seedlings. As of June 9, 2000, 76 percent of HQ seedlings sustaining browse damage had damage to the terminal leader, while browsing of terminal leaders occurred in 100 percent of HQC and ST seedlings.

October mean percent mortality of ST seedlings was significantly greater than mortality in HQC seedlings, but not significantly greater than HQ seedlings (figure 4). Although differences between planting and competition control treatments were not statistically significant, mean percent mortality of ST seedlings was highest (30 percent) in random plots receiving competition control. Twenty-seven percent of the HQ seedlings that died and 11 percent of the ST seedlings that died had experienced browsing. The single HQC seedling that died was also browsed.

DISCUSSION AND CONCLUSIONS

Limited vegetation development, limited loblolly pine seedling growth, and low levels of browsing and competition during the first growing season may account for the lack of statistically significant differences between planting and competition control treatments. Competition between planted seedlings and other herbaceous and woody plants is expected to increase with time as stump sprouts and other vegetation continue to develop. Similarly, the impact of competition control treatments should increase as well. The l-0 loblolly pine seedlings planted likely had little effect in shielding the larger planted oaks from browsing due to their small size. Loblolly pine seedlings were only half the height of most HQ oak seedlings during the 2000 growing season. Browsing was also lighter than expected.

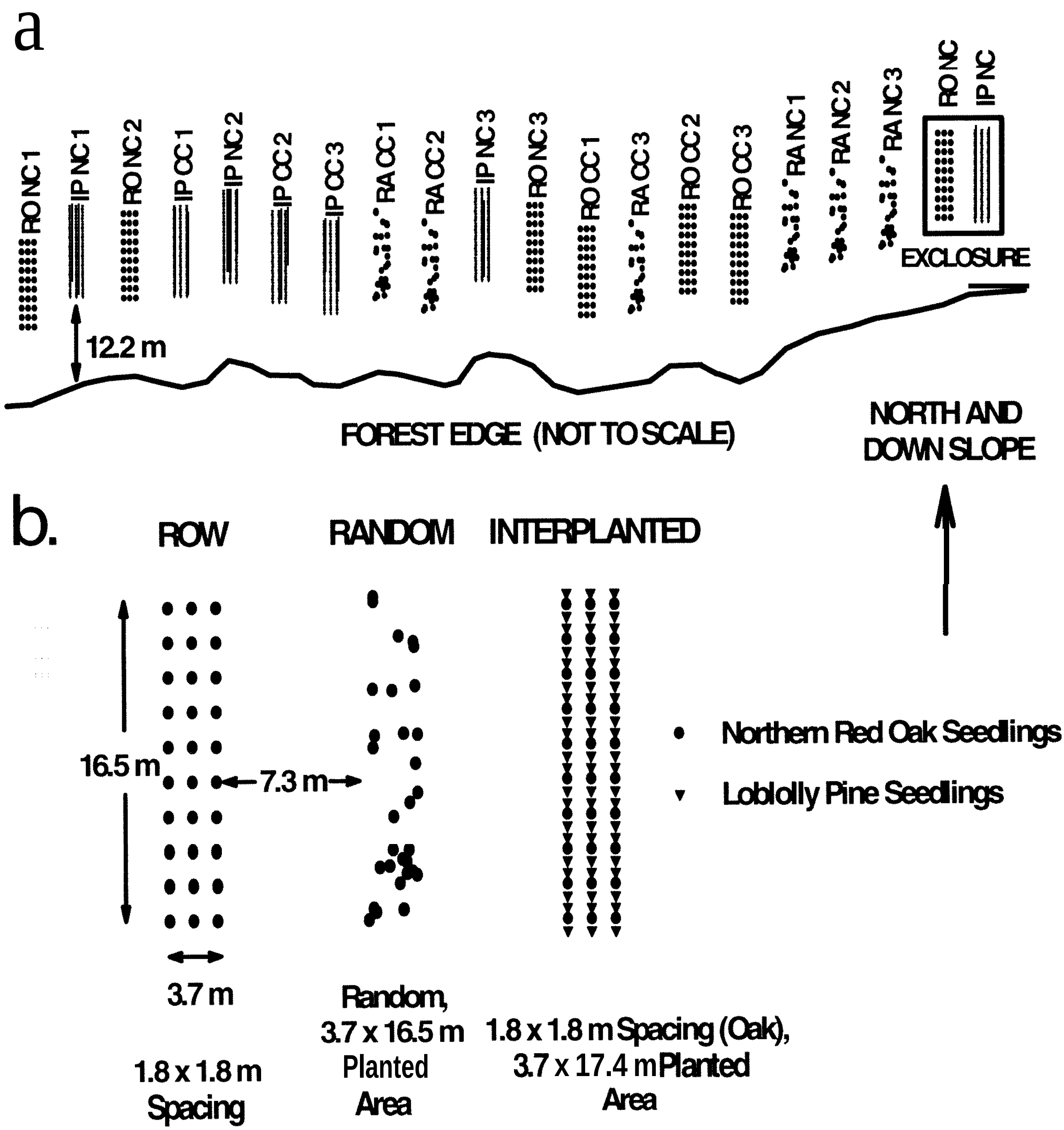

Figure I-Layout of study (a) and planting patterns (b). RO = row, RA = random, IP = inter-planted. CC = competition control and NC = no competition control. Each plot contains 15 HQ seedlings, 5 HQC seedlings, and 10 ST seedlings.

The patterns in height growth between seedling types observed were consistent with previous predictions (Kormanik and others 1995). Mean height growth of HQ, HQC, and ST seedlings appeared to be closely correlated with seedling height at the time of planting. However, differences in nursery practices, stem diameter, the number of first-order lateral roots, and overall biomass could have contributed to these differences as well.

Differences between seedling types in the incidence of deer browsing may be related to differences in apparency and nutritional value. In contrast to ST seedlings, the shoots of HQ and HQC seedlings often extended well above competing vegetation. This difference in canopy position may have resulted in much greater apparency of HQ and HQC seedlings to deer. Similar effects of understory vegetation have been reported previously (Buckley and others 1998, Gottschalk and Marquis 1983). More frequent browsing of HQ and HQC seedlings may also be related to greater nutritional value imparted by the HQ nursery protocol.

Several factors may have contributed to seedling mortality: poor microsites, competition, browsing, and overspray of glyphosate. All seedlings were susceptible to potentially poor microsite conditions and competition prior to application of the competition control treatment. Browsing may have played a role in the mortality of a percentage of seedlings, particularly HQ seedlings. Accidental application of glyphosate killed several small ST seedlings hidden by vegetation in plots receiving competition control, particularly in random plots.

Based on first-year results, HQ seedlings appear most promising in terms of growth, although survival was greatest for HQC seedlings. The consequence of the heavier browsing experienced by HQ seedlings remains an important question. Whether these seedlings are successful in rapidly escaping the reach of deer, or whether repeated browsing will compromise their advantage over ST seedlings is unknown. Browsing may be of minimal importance on some sites, but deer populations are increasing in parts of Tennessee and elsewhere. It also unclear whether effects of planting and competition control treatments will strengthen. Long-term monitoring of seedling performance is planned.

ACKNOWLEDGMENTS

I thank Scott Schlarbaum for supplying seedlings, and Richard Evans and his crew for helping implement the study. I also thank Brien Ostby, Leslie Chadwell, Chad Christman, and Jason Willis for their help in planting and in data collection. This work was supported by McIntire-Stennis funds.

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