Field Performance of Nuttall Oak on Former Agricultural Fields: Initial Effects of Nursery Source and Competition Control

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Abstract: Nuttall oak (*Quercus nuttallii* Palm.) seedlings raised at state nurseries in Mississippi, Louisiana, and Arkansas were morphologically different in height, root collar diameter, fresh mass, number of first-order lateral roots, root volume, and height-to-root collar diameter ratio. When outplanted on afforestation sites in the Lower Mississippi Alluvial Valley, nursery source did not significantly affect seedling survival or height and diameter growth 2 years after outplanting. Competing herbaceous vegetation reduced Nuttall oak seedling survival by 8%, height growth by 69%, and root collar diameter growth by 61% 2 years after outplanting. Nursery source did influence the ability of Nuttall oak seedlings to overcome transplant stress. Greatest durations of planting check were observed on seedlings raised at Nursery B and C, particularly those competing with herbaceous vegetation.

Keywords: *Quercus nuttallii*, hardwoods, seedlings, afforestation, transplant stress index

Introduction

Bottomland hardwood seedling demand has solidified over the past 2 decades as afforestation practices progress in the Lower Mississippi Alluvial Valley (LMAV) and other bottomland regions throughout the southern United States. This land use trend, which favors conversion of economically marginal agricultural land to hardwood forest plantations, is motivated by governmental conservation programs including the Wetland Reserve Program (WRP) and the Conservation Reserve Program (CRP) (Stanturf and others 2000). Such programs have been widely successful in removing significant acreage from agricultural production. For example, it is estimated that between 1991 and 2001, more than 345,000 ac (139,600 ha) of bottomland hardwood plantations were established through the WRP in the tri-state area of Louisiana, Mississippi, and Arkansas (Gardiner and Oliver 2005).

While acreage enrollment in various conservation programs continues, some question whether or not these extensive operations have fostered successful bottomland hardwood plantation establishment. Indeed, an evaluation of WRP tracts planted

in Mississippi in 1992 revealed a very low rate (<25%) of plantation establishment success (Schweitzer 2004). Much of the poor success may be attributed to afforestation practices, including unacceptable planting procedures, inappropriate species/site assignments, and inadequate site preparation practices. But, part of the poor success may also be attributed to the outplanting of inferior seedlings. Production and subsequent planting of apparently inferior seedling stock may be a result of the sudden increase in the number of nurseries producing hardwood seedlings and/or a lack of knowledge needed to define quality parameters of bottomland hardwood seedlings.

Current recommendations for hardwood seedling specifications evolved from decades of practical experience and observations gained by practitioners and researchers working in bottomland hardwood nurseries and on regeneration sites. While much pragmatic information on hardwood seedling nursery culture and afforestation has accumulated over the years, many current recommendations and guidelines have no scientific basis. For example, currently used recommendations for seedling heights were initially established for "ease of handling" (McKnight and Johnson 1966, 1975, 1980). The lack of scientifically-based standards for hardwood seedling quality has resulted in the implementation of arbitrary seedling quality specifications, which often differ among state and federal agencies. Furthermore, seedling quality specifications rarely account for inherent differences in morphology and growth between seedlings of the various bottomland hardwood species.

This manuscript reports on one aspect of a larger research effort designed to examine linkages between nursery practices, seedling morphology, and outplanting performance of several bottomland hardwood species commonly planted on afforestation sites in the LMAV. The purpose of this manuscript is to report 2-year findings on survival, growth, and planting check of Nuttall oak (*Quercus nuttallii* Palm.) produced at three different nurseries and grown under two different levels of competition.

Materials and Methods

Seedling Material and Laboratory Procedures

Seedling material for this research was procured from three state-managed nurseries: (1) Winona Nursery, which is managed by the Mississippi Forestry Commission; (2) Monroe Nursery, which is managed by the Louisiana Department of Agriculture and Forestry; and (3) Baucum Nursery, which is managed by the Arkansas Forestry Commission. At each nursery, personnel lifted and bagged approximately 1,500 bareroot Nuttall oak seedlings on 30–31 January 2003. We received the experimental seedlings on these dates, and stored them under air temperatures of 4 °C (40 °F) in coolers located at the Center for Bottomland Hardwoods Research, Stoneville, MS, and the Theodore Roosevelt National Wildlife Refuge Complex, Hollandale, MS.

Processing and measurements to characterize seedling morphology began on 4 February 2003. To prepare seedlings for measurement of various morphological variables, soil and root dip were washed away from root systems, and a plastic adhesive tag bearing an identity number was affixed to the shoot. Stem length (cm), root collar diameter (mm), fresh weight (g), root volume (cm^3), and number of first-order lateral roots were measured on each seedling in the laboratory.

Following laboratory measurements, seedlings were randomly assigned to a site and treatment plot, and then bagged according to these factors. Bagged seedlings were returned to coolers where they were stored until outplanting. The laboratory measurement and seedling storage period extended less than 1 month after lifting, and all seedlings were planted on respective study sites by 26 February 2003.

Field Sites

Seedlings were outplanted on three former agricultural sites enrolled in either the WRP or CRP, and located in the MS, LA, and AR portions of the LMAV. Agricultural crops were raised on all three sites during the growing season prior to study establishment, and these sites did not receive site preparation treatments prior to planting. Soil on the site in Chicot County, AR, is mapped as the Perry series (very-fine, smectitic, thermic Chromic Epiaquerts). Soil on Madison Parish, LA, and Boliver County, MS, sites is mapped as the Sharkey series (very-fine, smectitic, thermic Chromic Epiaquerts).

Experimental Design

The experimental layout in the field was designed to allow for testing the effects of nursery source (three levels) and weed control (two levels) on the various response variables listed below. Levels of nursery source included the MS, LA, and AR nurseries, while levels of weed control included complete weed control and none. To accommodate this design, three replicate blocks of six treatment plots were established on each site. Each treatment plot consisted of a 5 by 10 grid of planting spots spaced 1.8 m (6 ft) apart. In each block, the 6 treatment combinations of nursery source and weed control were randomly assigned to plots.

Field Practices

Hardwood planting shovels having a blade width of 16.5 cm (6.5 in) and length of 25 cm (10 in) were used to hand-plant seedlings in treatment plots. The MS site was planted by the authors and technical assistants, while the other two sites were planted by a contracted professional planting crew. After seedlings were planted, chemical and mechanical weed control practices were implemented as needed during the first growing season to exclude all competing vegetation from plots designated to receive weed control. Herbicides used on these plots included oxyfluorfen, clethodim, and glyphosate, while mechanical methods of vegetation control included hoeing, mowing, and disking. Seedling height and root collar diameter were measured in the field immediately after planting, and following the first and second growing seasons.

Data Analyses

Analyses of seedling survival, height growth, and root collar diameter growth were conducted according to a randomized block design with nursery source and weed control as the main factors in the model. Means were separated with Tukey's HSD test if an effect was significant at the 0.05 probability level. To assess if nursery source or herbaceous competition impacted planting check of outplanted seedlings, we calculated values for Transplant Stress Index for each treatment combination according to methods outlined by South and Zwolinski (1996). For presentation of results and discussion, the identities of nurseries were concealed. Therefore, nurseries are referenced in the remainder of the manuscript according to a randomly assigned code, A, B, or C.

Results and Discussion

Seedling Characterization

Planting date, sowing density, seed source, cultural practices, and irrigation and fertilization regimes are among the many factors that can impact growth and development of hardwood seedlings in nursery beds. Thus, it is expected that the morphological characteristics of bareroot stock is quite variable (Jacobs and others 2005), and some of this variation can be related to nursery source. In this experiment, bareroot Nuttall oak stock obtained from state nurseries in MS, LA, and AR differed substantially in shoot and root morphology. Seedlings raised in Nursery B were the largest, having a fresh mass 77 to 122% larger than stock from the other nurseries (fig. 1). Along with the greatest fresh mass,

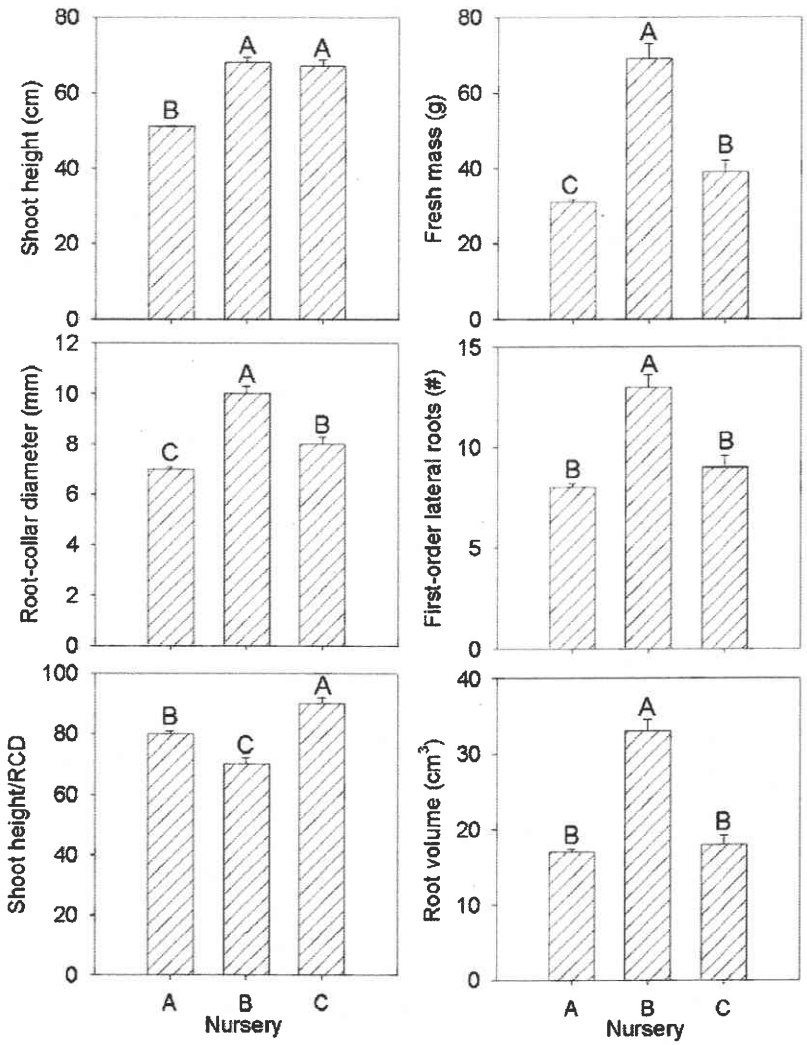

Figure 1—Morphological characteristics of Nuttall oak seedlings produced at three different nurseries. Different letters above bars indicate nursery source differences at the 0.05 probability level.

these seedlings showed the highest number of first-order lateral roots (FOLR), the highest root volume of the examined sources, and the most balanced shoot height-to-root collar diameter ratio (fig. 1). In contrast, seedlings raised at Nursery A were 24% shorter than those grown at the other nurseries, had the smallest root collar diameter, and were the smallest in fresh mass (fig. 1). Seedlings with the most unbalanced shoot height-to-root collar diameter ratio were produced at Nursery C (fig. 1).

Seedling Survival

Seedling survival can be problematic on afforestation sites in the LMAV for a multitude of reasons related to seedling quality, handling practices, planting practices, and site conditions (Stanturf and others 2004). Nuttall oak seedlings outplanted in this study showed survival rates that averaged 89% across all planting sites in year 1, and 87% in year 2 regardless of nursery source (table 1). These survival rates were as high as or higher than rates reported for Nuttall oak observed in other experimental plantings in the LMAV (Miwa and others 1993; Schweitzer and others 1997; Schweitzer and others 1999). Our initial results indicate that mortality was not influenced by seedling source, and all three nurseries produced Nuttall oak seedlings able to survive outplanting on afforestation sites in the LMAV.

Herbaceous competition, which grows vigorously on former agricultural fields, is often implicated as a primary source of seedling mortality on afforestation sites (Stanturf and others 2004). Findings from this research support this assertion, as seedlings planted among herbaceous competitors showed 55% greater mortality in year 1 and 51% greater mortality in year 2 than seedlings established in plots receiving competition control (table 2). While these initial results indicate that nursery source did not impact early survival of outplanted Nuttall oak seedlings, gains in seedling survival on former agricultural fields could be achieved through practices that reduce competition from herbaceous weeds.

Table 1—Nuttall oak seedling survival according to nursery source.

Nursery	Year 1[a]	Year 2[a]
A	90.3 ± 1.3 a	88.3 ± 1.6 a
B	90.4 ± 1.7 a	88.9 ± 1.9 a
C	87.5 ± 1.7 a	84.5 ± 2.0 a

[a] Mean separations are for nurseries within a given year such that means within a column followed by a different letter are different at alpha = 0.05.

Table 2—Nuttall oak seedling survival according to competition control treatment.

Competition control	Year 1[a]	Year 2[a]
Non-weedy	91.8 ± 1.0 a	88.9 ± 1.0 a
Weedy	87.2 ± 1.4 b	83.2 ± 1.6 b

[a]Mean separations are for competition control treatment within a given year such that means within a column followed by a different letter are different at alpha = 0.05.

Seedling Growth

Corresponding to measurements of stem length in the laboratory, initial seedling heights measured in the field illustrate that seedling morphology varied by nursery. Average height of outplanted seedlings ranged between 47 and 63 cm (18.5 and 25 in) for the various nursery sources (figs. 1 and 2), but this did not appear to influence height growth. Height of outplanted seedlings increased an average of 13 cm (5 in) during the first growing season, and 39 cm (15 in) the second growing season regardless of nursery source (fig. 2). Likewise, initial differences according to nursery source were noted for seedling root collar diameter, which ranged

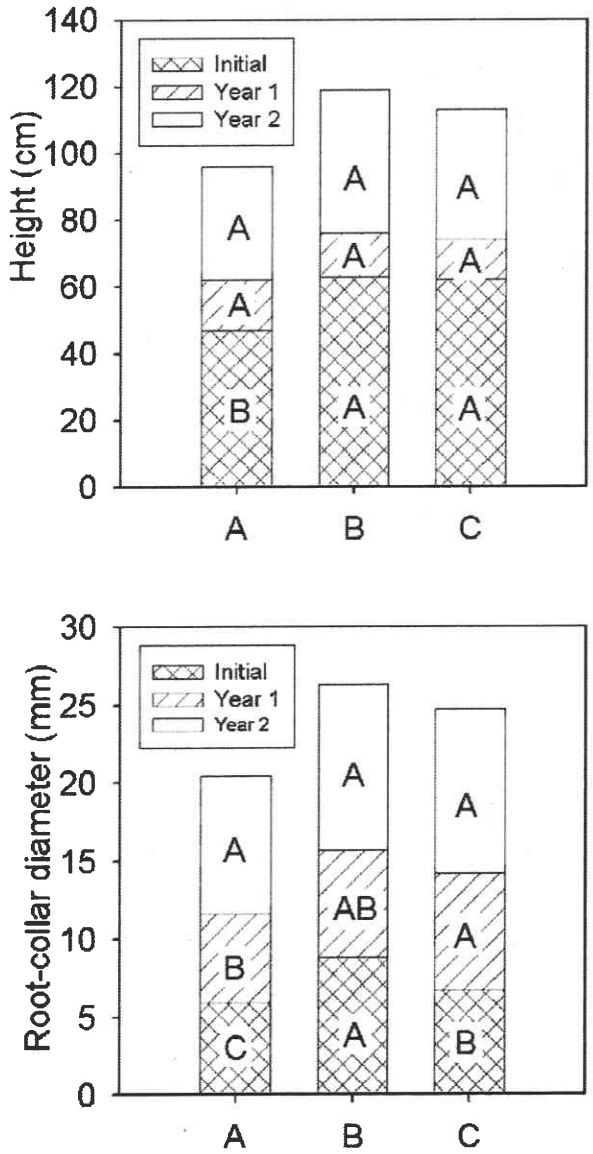

Figure 2—Initial seedling size, height growth, and root collar diameter growth for Nuttall oak seedlings relative to nursery source two growing seasons after outplanting.

between 5.9 and 8.8 mm (0.2 and 0.3 in) immediately after outplanting (fig. 2). Root collar diameter growth during the first growing season ranged from 5.7 and 7.5 mm (0.2 and 0.3 in) between the three nursery sources (fig. 2), but this difference was lost in the second growing season when all sources averaged a 10.0 mm (0.4 in) increment (fig. 2).

Reported shoot growth of bareroot Nuttall oak seedlings planted on former agricultural land is variable. Miwa and others (1993) noted Nuttall oak height growth averaged 19 cm (7.5 in) during the first season after planting, while Williams and Craft (1998), who conducted a study on the same site, reported a net loss (–12 cm [–5 in]) in seedling height during the first growing season after planting. In this study, seedling height and root collar diameter were substantially increased with competition control treatments (fig. 3). Seedlings that received competition control developed shoots 72% taller than those that did not receive competition control (fig. 3). Likewise, root collar diameters on these stems were 87% larger than seedlings that did not receive competition control (fig. 3). Results from this study do not identify nursery source as a significant determinant of early shoot growth, but clearly indicate that herbaceous competition can severely limit shoot growth of Nuttall oak seedlings outplanted on former agricultural fields.

Seedling Planting Check

The Transplant Stress Index (TSI), proposed by South and Zwolinski (1996), quantifies the reduction in terminal growth often experienced by transplanted seedlings to provide a morphological index of planting check. Application of the TSI has proven useful for documenting planting check of many conifer species, but its use has rarely been extended to periodic flushing species, such as oaks. In this study, calculated values for TSI indicated that severity of planting check observed on outplanted Nuttall oak seedlings varied according to nursery source and competition control treatments (table 3). Planting check was not evident for seedlings produced in Nursery A, as TSI values were positive regardless of year or competition control treatment (table 3). For seedlings produced in Nursery B, those which received weed control did not exhibit planting check, but seedlings that did not receive weed control showed planting check the first year in the field. Seedlings produced in Nursery C exhibited planting check in year 1 regardless of whether they were established under weedy competition or not. By the end of the second growing season, those receiving competition control showed recovery from planting check, while those established amongst weeds were still stressed from the transplanting process (table 3). It is apparent that stock obtained from each of the three nurseries exhibited differing abilities to overcome transplanting stress, and the presence of competing herbaceous vegetation prolonged planting check for some sources. We have yet to identify the mechanisms that allowed some sources to overcome planting check relatively quicker than others.

Summary

Though bareroot Nuttall oak seedlings raised at three different nurseries developed differing shoot and root

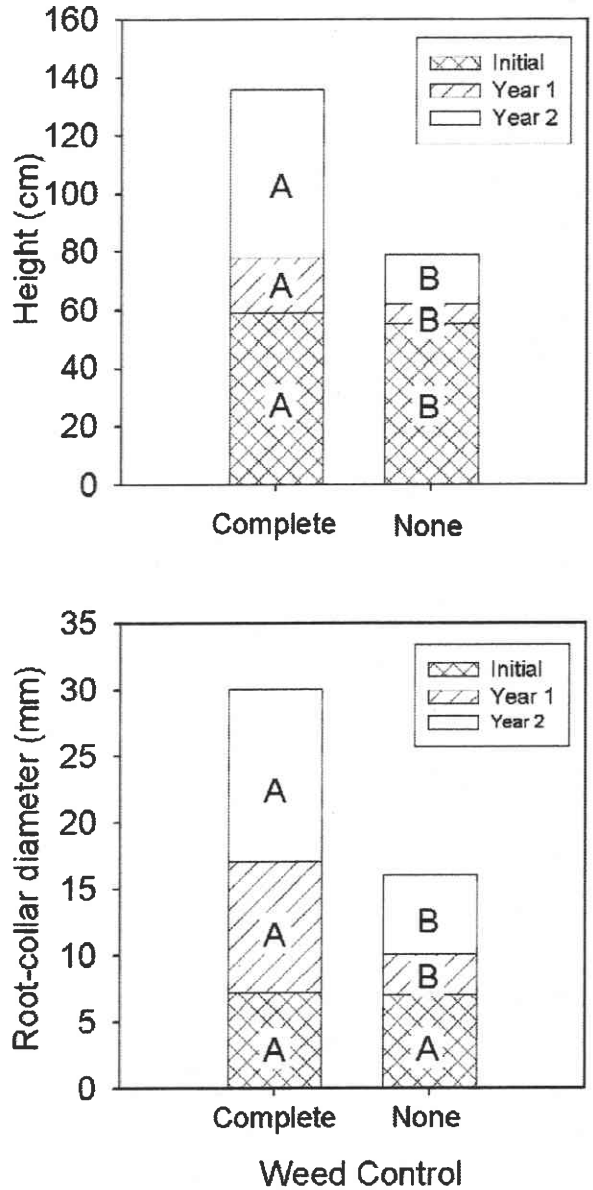

Figure 3—Initial seedling size, height growth, and root collar diameter growth for Nuttall oak seedlings relative to two levels of weed control. Different letters for a sample period indicate weed control differences at the 0.05 probability level.

Table 3—Transplant Stress Index values for Nuttall oak seedlings outplanted from three nurseries and subjected to two levels of competition control.

Nursery	Competition control	Year 1	Year 2
A	Non-weedy	2.8	1.3
	Weedy	1.1	2.4
B	Non-weedy	1.9	1.3
	Weedy	0.0	2.2
C	Non-weedy	–0.4	1.7
	Weedy	–0.1	–0.2

morphologies, survival and growth of different sources varied little 2 years after outplanting on former agricultural land in the LMAV. Competition from herbaceous vegetation, however, did increase seedling mortality by 51%, reduced height growth by 69%, and root collar diameter growth by 61% 2 years after outplanting. Planting check duration for Nuttall oak seedlings was determined in part by nursery source, and herbaceous competition lengthened the period of planting check, particularly for stock from Nurseries B and C. To improve field performance of bareroot Nuttall oak seedlings on afforestation sites in the LMAV, future investigations should focus on practical methods of herbaceous vegetation control on afforestation sites, and identifying nursery practices that foster production of seedlings with the ability to rapidly recover from transplant stress. In addition to research on bareroot stock, transplant stress of Nuttall oak could potentially be reduced through the development of quality container stock.

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