Artificial Regeneration of Northern Red Oak in the Lake States With a Light Shelterwood: A Departure From Tradition

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Abstract: Artificial regeneration of northern red oak is difficult to achieve in the Lake States. A replicated study was established in northern Wisconsin in 1990 to determine the effect of overstory density and understory competition on the performance of bareroot and containerized northern red oak seedlings on a dry-mesic site. The relationship between seedling performance and the number of first-order lateral roots was also tested. Seedling performance was evaluated under three overstory densities—clearcut, 25%, and 50% crown covers—in combination with (or without) understory vegetation control with herbicide. Height growth was greater for containerized seedlings than for bareroot seedlings after two and three growing seasons. After 2 years, seedling growth was greatest in the sprayed clearcut plots, but was only slightly greater than the unsprayed plots under the 25% crown cover (bareroot 25.5 vs. 23.8 cm, and containerized 33.0 vs. 31.2 cm, respectively). After 3 years, seedling height growth (containerized and bareroot) was significantly greater in the unsprayed plots under the 25% crown cover than in all overstory/understory treatment combinations examined. These early results suggest that the light shelterwood (25% crown cover) treatment may be a good alternative over the more traditional management scheme of establishing seedlings under a medium density shelterwood (70% crown cover) with total overstory removal at a later date.

Developing an effective regeneration system is a key aspect of managing any tree species. The primary goal of an artificial regeneration system is to establish a vigorously growing seedling as economically as possible. To achieve this goal, conditions must be created through cultural practices and manipulation of the microenvironment to meet the biological needs of the species. In all cases, these systems should be viewed on a site-specific basis until the forest manager has the knowledge to generalize across site types.

Northern red oak (*Quercus rubra* L.) is one of the most valuable hardwood species in the Lake States. However, at present forest managers do not have reliable site-specific regeneration systems for red oak in the region. Successful regeneration systems have been developed for northern red oak in the central hardwoods region that include a one-or two-cut shelterwood, competition control, planting bareroot stock with a caliper of 9.5 mm (3/8 inch) or greater, followed by removal of the shelterwood after 3 years (Johnson et al. 1986). Traditionally, shelterwood systems that retain a crown cover of about 70% have been prescribed for regeneration of northern red oak. In fact, regeneration failures are predicted if the overstory is reduced to 50% crown cover or less (Sander 1979, Loftis 1983). In addition, Lorimer (1989) suggests that the sluggish growth habits of oak are responsible for regeneration failures with shelterwood management, and that any type of overstory reduction will only lead to the replacement of oak by other species. However, attempts at artificial

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regeneration of northern red oak with medium density shelterwood management (e.g., 70% crown cover) have failed in the upper Great Lakes region, probably because of use of poor planting stock, improper planting and handling practices, intense understory competition, inadequate site preparation, and insufficient light to support sustained growth during establishment phases.

Planting stock of the size recommended by Johnson cannot be produced in a single year in northern nurseries, and 2-0 stock is more costly and often too large to be planted efficiently. Although there is some correlation between root collar diameter and field performance, there is growing evidence that the number of first-order lateral roots on a seedling may be a better predictor of field performance (Kormanik 1989). Recent modifications of nursery cultural practices have led to an increase in the overall seedling size and the number of first-order lateral roots on 1-0 northern red oak nursery stock (Buchschacher et al. 1991). However, production of 1-0 northern red oak in northern regions is still not up to the standards outlined by Johnson. Seedlings with at least six lateral roots are used successfully for regenerating northern red oak (Schultz and Thompson 1991), and seedlings with more lateral roots may permit the use of somewhat smaller stock than recommended by Johnson.

The growth potential of northern red oak is believed to be highest in full light conditions on rich mesic sites. Planting seedlings in such conditions usually requires herbicide applications to control competing vegetation. Environmental concerns have led to a reduction in the use of herbicide on some public lands, and control of vegetation by the use of herbicides may not be a viable management option in the future. Northern red oak also grows reasonably well on drier sites (i.e. dry-mesic) where understory competition is less intense. Kotar (1991) suggested that these sites may offer the best opportunities for oak regeneration in the Lake States. We conducted a study to develop an artificial regeneration system for northern red oak on dry-mesic sites in northern Wisconsin. Our study was designed to evaluate overstory density (i.e. crown cover), competition control, stock type, and the number of lateral roots on bareroot seedlings as components of the regeneration system.

MATERIALS AND METHODS

The study was conducted within a mixed northern hardwood stand consisting of predominately paper birch (*Betula papyrifera* Marsh.), red maple (*Acer rubrum* L.), and northern red oak on the American Legion State Forest near Lake Tomahawk in northern Oneida County, Wisconsin. The site is a moderately fertile, dry-mesic site with sandy loam soils and habitat type AVVib (Acer/ Vaccinium - Viburnum) according to Kotar et al. (1988). The site index for northern red oak is 18.6 m (61 ft) (at age 50). The study design is a randomized complete block with a split-plot arrangement of treatments. It consists of three 0.3-ha (0.75-acre) replications of each of three overstory densities—clearcut, 25% crown cover, and 50% crown cover,—and two levels of herbicide—sprayed and unsprayed (Figure 1). A 9.8 meter (32 ft) buffer area of the same overstory density surrounds each plot, making each unit area 0.57-ha.(1.4-acre). Harvesting was by whole tree skidding in January and February 1989 to minimize soil disturbance and residual slash on the site. Tables based on the relationship between tree diameter and crown area (Godman and Tubbs 1973) modified by G. Erdmann (unpublished) were used to mark trees to the prescribed crown cover. Glyphosate (Roundup[2]) herbicide was broadcast sprayed on half of each plot at a rate of 4.7 l/ha (2 qts/acre) in September 1989. The entire study area was enclosed by a high tensile electric fence to minimize the impact of deer browse.

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[2]The mention of trade names is for the information of the reader and does not constitute endorsement by the U.S. Department of Agriculture, Forest Service.

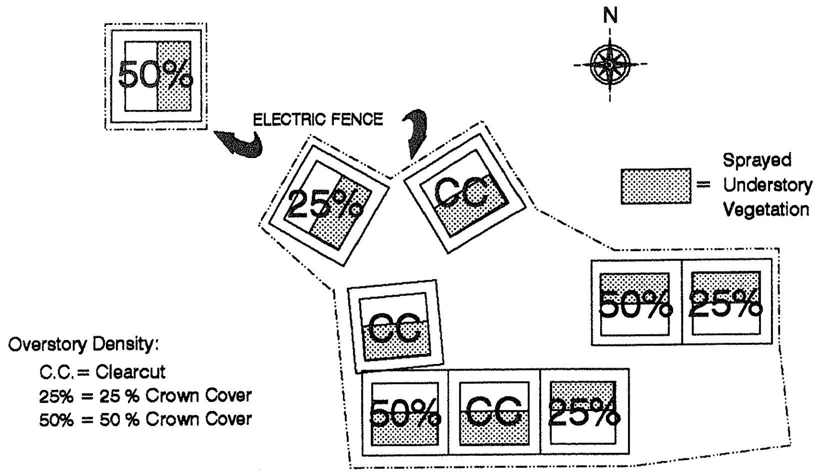

Figure 1.—Overview of Bird Lake oak regeneration site. Each overstory treatment plot is 0.75 acre with a 32 ft. buffer strip around the perimeter.

In May 1990, seedlings were planted within the study area for two separate experiments. In one experiment, we compared the responses of bareroot versus containerized seedlings among the overstory density and herbicide spray treatments. The bareroot seedlings had at least 10 permanent first-order lateral roots (roots > 1 mm in diameter at the point of attachment to the taproot), a minimum stem height of 13.0 cm, and caliper of 7.0 mm These seedlings had an average height of 31.5 cm and average caliper of 7.6 mm (Table 1). The containerized seedlings were grown in 10 x 36 cm (4 x 14 in) 4-ml polyethylene pots in the greenhouse for one-year. The containerized seedlings had a minimum 20 cm stem height and 3.8 mm caliper, and averaged 29 cm in height and 5.7 mm in caliper.

In the second experiment, seedling performance was compared by root-grade (i.e. the number of lateral roots > 1 mm in diameter). The seedlings were graded as follows: grade 1, 0 to 5 lateral roots; grade 2, 6 to 10; grade 3, 11 to 15; grade 4, 16 to 20; and grade 5, more than 20 laterals. The root-graded seedlings had a minimum stem height of 8 cm and caliper of 3.9 mm and averaged 21 cm in height and 6.0 mm in caliper (Table 1).

All seedlings were planted in 10-cm-diameter augered holes. The study included 48 bareroot, 12 containerized, and 35 root-graded seedlings (i.e. 5 grades x 7 seedlings/grade) in each overstory x spray treatment plot, for a total of 1710 seedlings in the study.

Seedling performance is reported here for 2 and 3 years after planting. Height growth is expressed as 2-year cumulative growth (seedling height after 2 years minus planting height), and third-year growth (the difference between total seedling height after 2 and 3 years). Some seedlings had a negative net growth in the third year because of partial dieback. The negative growth values for these seedlings were included for analysis, but seedlings that died back to the ground and did not resprout were excluded. Statistical analysis was by analysis of variance for split-plot designs with SAS (1988).

Table 1.—Mean establishment height and caliper of bareroot, containerized, and root-graded seedlings.

	Height (cm) Mean ± SE	Caliper (mm) Mean ± SE
Bareroot[a]	31.5 ± 0.31	7.6 ± 0.03
Containerized	29.1 ± 0.32	5.7 ± 0.04
Root graded[b]	21.1 ± 0.32	6.0 ± 0.04

[a]Bareroot seedlings had a minimum of 10 lateral roots > 1 mm diameter

[b]Root grades: 1 = 0-5 laterals > 1 mm; 2 = 6-10 laterals > 1 mm; 3 = 11-15 laterals > 1 mm; 4 = 16-20 laterals > 1 mm; 5 = > 20 laterals > 1 mm

RESULTS AND DISCUSSION

Survival

Overall, seedling survival was high throughout the study, reflecting the benefit of planting high quality stock. After 2 years, average survival ranged from 98% for the containerized seedlings to 99% for the bareroot seedlings. After 3 years, survival ranged from 94% for the containerized seedlings to 98% for the bareroot seedlings. Specifically, the 3-year survival for the bareroot seedlings ranged from 95% in the unsprayed clearcut plots to more than 99% in the unsprayed, 50% crown cover plots. The survival range for containerized seedlings was from 86% in unsprayed, 25% crown cover plots to 100% in sprayed, 50% crown cover plots.

Seedling Performance

Containerized vs Bareroot Seedlings

Containerized seedlings had much better height growth than bareroot seedlings after two and three growing seasons. After two growing seasons, growth of both seedling types was significantly greater in the clearcut and 25% crown cover plots than in the 50% crown cover plots (Figure 2). However, in the third year, performance declined in the clearcut plots for both types of seedlings. The best growth for both bareroot and container stock occurred in the unsprayed, 25% crown cover plots. The containerized seedlings grew more than the bareroot seedlings even though the average height of the containerized seedlings at establishment was less than that of the bareroot seedlings (29.1 cm vs. 31.5 cm, respectively) (Table 1).

Containerized Seedlings

Two-year cumulative growth of containerized seedlings was greatest in the sprayed clearcut plots, but not significantly greater than in the unsprayed 25% crown cover plots. Growth was significantly less but statistically equal in all other overstory density/spray treatment combinations, except in the sprayed 50% crown cover plots where growth was the poorest (Figure 3). After three growing seasons, containerized seedling growth was greatest in the unsprayed 25% crown cover plots, and statistically less in all other treatment plots. Net growth was negative in unsprayed clearcut plots.

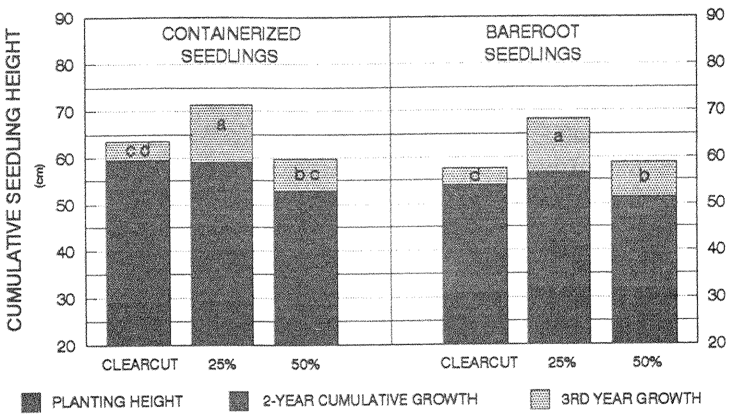

Figure 2. —Cumulative seedling height at planting date and after two and three growing seasons for containerized and bareroot seedlings growing under three overstory densities (clearcut, 25% crown cover, and 50% crowncover). Growth segments labeled with the same letter are not significantly different for the respective growth periods. (P=0.05)

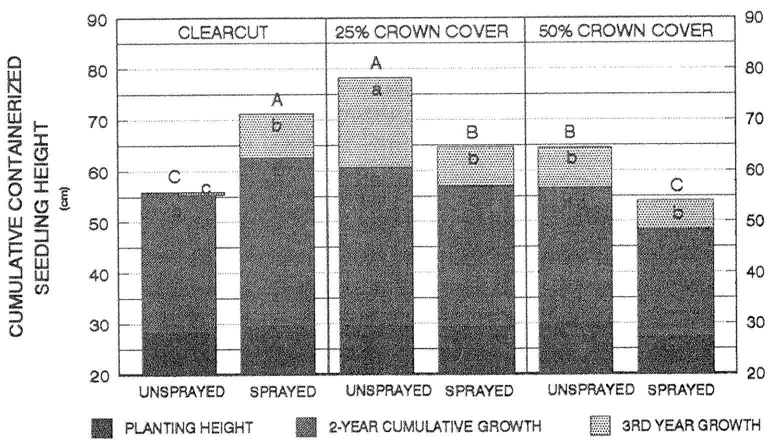

Figure 3.—Cumulative height of containerized seedlings at planting date and after two and three growing seasons relative to overstory density and herbicide spray treatments. Growth segments labeled with the same letter are not significantly different for the respective growth periods. Capital letters represent significant differences in total seedling height after 3 years. (P=0.05)

We believe the reduced growth in the clearcut can be attributed to rapid invasion of competing vegetation and to seedling dieback caused by a late spring frost in 1992. Herbicide spraying temporarily reduced the density of competing vegetation in the clearcut in the first 2 years, but the vegetation redeveloped rapidly in the third growing season, causing interference and reducing availability of resources for oak seedling growth. The frost damage, although not extensive, occurred only in the clearcut plots and not in any of the shelterwood plots. Similar frost damage occurred at another study site approximately 32 km (20 miles) west of this site; 100% of the seedlings in an 8-ha (20 acre) clearcut were severely damaged by frost, but there was no damage in adjacent shelterwoods of 50% crown cover and 75% crown cover.

Bareroot Seedlings

Bareroot seedling performance was relatively uniform for the first two growing seasons, with only slightly better growth (although statistically significant) in the sprayed clearcut, and both sprayed and unsprayed 25% crown cover plots (Figure 4). During the third growing season, more dramatic treatment differences appeared. The greatest seedling growth was under the 25% crown cover, where growth was statistically greater in the unsprayed plots than in the sprayed. Growth was significantly less in the other overstory/understory treatment plots, with the poorest growth in the unsprayed clearcut plots.

The single condition that is consistent with "best" seedling growth for both types of seedlings after two and three growing seasons, is the unsprayed 25% crown cover. Seedling growth was similar in the sprayed clearcut plots after two years, but declined in the third year (1992). As mentioned previously, a June, 1992 frost caused considerable damage to seedlings on this and other sites in northern Wisconsin, and certainly contributed to the reduction in growth in these plots. Because there was not a significant difference in growth (for both type of seedlings) between the sprayed and unsprayed treatments in the 50% crown cover plots, it appears that the more dense overstory

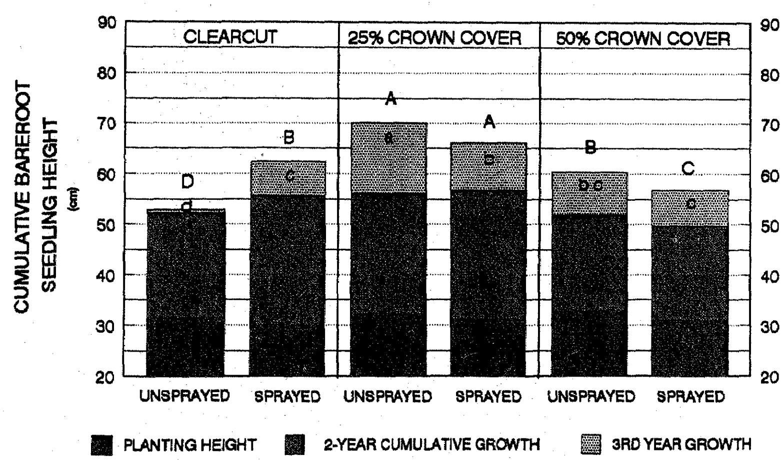

Figure 4.—Cumulative height for bareroot seedlings at planting date and after two and three growing seasons relative to overstory density and herbicide spray treatments. Growth segments labeled with the same letter are not significantly different for the respective growth periods. Capital letters represent significant differences in total seedling height after 3 years. (P=0.05)

is having an overriding influence on light and other resource availability. The herbicide treatment apparently did not provide a benefit to seedling growth under the 25% overstory density on these sites as we expected. This trend, although examined here at an early stage in regeneration, is an especially important finding considering the recent concerns on the use of herbicides. It also illustrates the benefit of selecting sites with a habitat where understory competition is minimal, and conditions are adequate for sustained oak growth. These findings lead us to conclude that although the seedlings grow well in the sprayed clearcut plots, the "best" overall treatment for sustained seedling growth on this habitat type is a 25% crown cover shelterwood, with an unsprayed understory.

After three growing seasons, the poorest growth and most dieback and mortality in the 25% crown cover plots occurred in close proximity to stump sprouts that over-shadowed some planted seedlings. This reduction in growth and incidence of mortality is likely attributed to the micro-environment created by the stump sprouts and reduces the growth potential of the overall environment of the 25% crown cover treatment. Therefore, seedlings should not be planted in close proximity to stumps that are likely to sprout vigorously after harvesting. Studies are planned to quantify the light environment relative to the overstory density and lower canopy composition to better evaluate seedling performance in specific microenvironments. In the future, "best growth" is expected to be in the unsprayed 25% crown cover plots. Thus far the seedlings in those plots have grown to be the tallest in the study, and even greater growth is expected from the larger, well established seedlings.

ROOT-GRADED SEEDLINGS

We included root-graded seedlings in this study to test the hypothesis that the number of first-order lateral roots is correlated with field performance (Kormanik 1989). Two-year growth data pooled from all overstory/understory plots showed that grade 5 seedlings (seedlings with more than 20 lateral roots) grew an average 23.5 cm but there was no significant difference between grade 5 seedlings and grade 4 seedlings (x=21.5 cm). Grade 3 seedlings averaged 18.8 cm after two growing seasons, and grade 2 seedlings averaged 18.0 cm. However, there was no significant difference in two-year height growth among root grade 2, 3, and 4 seedlings. Grade 1 seedlings, with an average 2-year height growth of 12.5 cm, grew significantly less than all other root-graded seedlings (Figure 5). When seedling performance was analyzed relative to overstory density, 2-year

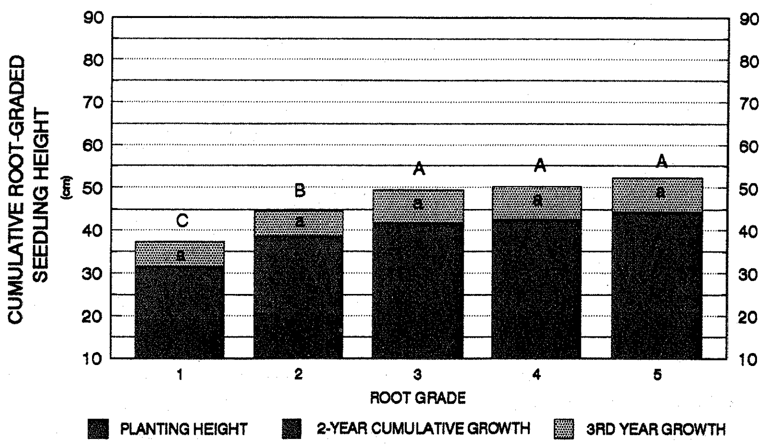

Figure 5.—Cumulative seedling height at planting date and after two and three growing seasons relative to root grade. Growth segments labeled with the same letter are not significantly different for the respective growth periods. Capital letters represent significant differences in total seedling height after 3 years. (P=0.05)

Table 2.—Average cumulative 2-year height growth ± SE (centimeters) for root-graded seedlings relative to overstory density.

Overstory density	Root grade				
	1	2	3	4	5
Clearcut	16.8 ± 2.9	18.8 ± 1.9	20.3 ± 2.3	25.4 ± 1.8	22.8 ± 2.4
25% Crown cover	11.5 ± 2.9	20.2 ± 2.4	20.8 ± 1.6	21.1 ± 2.1	26.0 ± 2.2
50% Crown cover	9.7 ± 1.9	14.7 ± 1.6	15.3 ± 1.5	17.6 ± 1.0	21.4 ± 2.0

Table 3.—Average third-year height growth ± SE (centimeters) for root-graded seedlings relative to overstory density.

Overstory density	Root grade				
	1	2	3	4	5
Clearcut	2.4 ± 4.5	2.2 ± 3.0	6.4 ± 2.0	5.0 ± 2.4	7.9 ± 2.2
25% Crown cover	7.3 ± 3.0	9.7 ± 2.4	8.7 ± 1.5	11.1 ± 2.2	8.7 ± 2.7
50% Crown cover	7.0 ± 1.5	5.6 ± 1.5	8.3 ± 1.5	7.0 ± 1.4	7.2 ± 1.8

cumulative height growth was poorest under the 50% crown cover for all root grades. We found that the higher grade seedlings performed better than the lower grade seedlings in all overstory densities (Table 2). Root grade made little difference in third-year seedling height growth (Table 3). Total height of the seedlings after 3 years was significantly greater for root grades 3 to 5 than for root grades 1 and 2, largely because of differences in growth during the first 2 years (Figure 5).

Although the use of 2-0 seedlings with a minimum caliper of 9.5 mm (3/8 inch) (Johnson et al. 1986) surely has merit, our study shows that smaller caliper seedlings can be successfully used in regeneration plantings if the seedlings have a significant number of first-order lateral roots. In the Lake States, large 2-0 nursery stock are not often used for artificial regeneration because of increased nursery costs associated with production, handling and shipping, and because of the belief that larger stock is more difficult to plant properly. This study illustrates the feasibility of using 1-0 nursery stock when essential criteria are met. The quality of the seedlings must meet minimum standards based on performance in the field. For this study, the bareroot seedlings had at least 10 first-order lateral roots greater than 1 mm in diameter and height of at least 13 cm and caliper of 7.0 mm. Although nurseries in the northern Lake States can produce 1-0 seedlings that meet these minimum standards, the percentage of cull seedlings in the seed bed is usually too high with standard nursery practices. However, with the utilization of quality seed sown at bed densities no greater than 85 per square meter (8 per square foot) and multiple applications of fertilizer at low rates (Teclaw and Isebrands 1991), seedling uniformity and quality can be improved dramatically, and a high percentage of 1-0 northern red oak seedlings can be produced that meet high quality standards.

SUMMARY

Our studies of artificial oak regeneration in the Lake States show that it must be viewed as a regeneration system, with the goal of obtaining an established, vigorous, free-to-grow seedling. The system that produces this seedling begins with the collection of high quality acorns and includes many steps—any of which may affect achieving the ultimate goal. Our early results suggest that the use of high quality seedlings, planted on dry-mesic sites, under a light overstory afford good conditions for the establishment of northern red oak without the use of herbicides. Our results also support Kotar's (1991) premise that dry-mesic sites are good sites on which to regenerate and grow northern red oak. Although regeneration systems that include clearcutting or two-cut shelterwoods may succeed in artificially regenerating oak in some regions, the species composition and its response to shelterwood management often differ by regions, suggesting that these methods cannot be universally applied. Moreover, the high probability of dieback due to late spring/early summer frosts in the Lake States may alone make artificial regeneration in clearcuts less successful in this region.

Although we now recommend high quality bareroot seedlings as the primary stock type for planting, our results suggest that containerized northern red oak seedlings merit future consideration. At present, production costs are high for containerized seedlings, but under the conditions of this study containerized seedlings outperformed bareroot seedlings over a 3-year period. Comparative studies on above and below ground morphology and carbohydrate reserves of bareroot and containerized seedlings need to be conducted to help us understand why the two types of seedlings perform differently.

In this paper we have outlined a successful artificial regeneration system for northern red oak on dry-mesic sites in the Lake States, based on 3-year results. The system departs from traditional methods in this region that use medium density shelterwoods and chemical control of competing vegetation to establish seedlings and total overstory removal at a later date for sustained growth. Our preliminary results suggest that on dry-mesic sites, light shelterwood cuts without herbicide spraying, and planting high quality nursery stock may be a successful alternative artificial regeneration system for forest managers to consider.

LITERATURE CITED

Buchschacher, G.L., P.T. Tomlinson, P.S. Johnson, and J.G. Isebrands. 1991. Effects ofseed source and cultural practices on emergence and seedling quality of northern red oak nursery stock. P. 126-130 in Proc. Sixth Biennial Southern Silvicultural Research Conf. Gen. Tech. Rep. SE-70.

Godman, R.M., and C.H. Tubbs. 1973. Establishing even-age northern hardwood regeneration bythe shelterwood method - a preliminary guide. USDA For. Serv. Res. Pap. NC-99, 9 p.

Johnson, P.S., C.D. Dale, K.R. Davidson, and J.R. Law. 1986. Planting northern red oak in theMissouri Ozarks: a prescription. North. J. Appl. For. 3:66-68.

Kormanik, P.P. 1989. Importance of first-order lateral roots in the early development of forest treeseedlings. P. 157-169 in Proc. Interrelationships between microorganisms and plants in soil, Vancura, V., and F. Kunc (eds.). Czechoslovak Academy of Sciences, Prague, Czechoslovakia.

Kotar, J. 1991. Importance of ecological classification in oak management. P. 132-140 in Proc. Theoak resource in the upper midwest: implications for management, Laursen, S.B., and J.F. DeBoe (eds.). Minn. Ext. Serv., Univ. of Minn., St. Paul.

Kotar, J., J.A. Kovach, and C.T. Locey. 1988. Field guide to forest habitat types of northernWisconsin. Dept. of For., Univ. of Wis. Madison and Wis. Dept. of Nat. Res., 212 p.

Loftis, D.L. 1983. Regenerating southern Appalachian mixed hardwood stands with the shelterwoodmethod. South. J. Appl. For. 7:212-217.

Lorimer, C.G. 1989. The oak regeneration problem: new evidence on cause and possible solutions.For. Res. Anal. No. 8. Dept. of For., Univ. of Wis. Madison, 31 p.

SAS Institute, Inc. 1988. SAS/STAT User's Guide. Release 6.03 Edition, Cary, NC,1028 pp.

Sander, I.L. 1979. Regenerating oaks with the shelterwood system. P. 54-60 in Proc. Regenerating oaks in upland hardwood forests. The 1979 John S. Wright Forestry Conference, Holt, H.A., and B.C. Fischer (eds.). Purdue Univ., West Lafayette, IN.

Schultz, R.C. and J.R. Thompson. 1991. The quality of oak seedlings needed for successfulartificial regeneration in the central states. P. 180-186 in Proc. The oak resource in the upper midwest: implications for management, Laursen, S.B. and J.F. DeBoe (eds.). Minn. Ext. Serv., Univ. of Minn., St. Paul, MN.

Teclaw, R.M. and J.G. Isebrands. 1991. Artificial regeneration of northern red oak in the LakeStates. P. 187-197 in Proc. The oak resource in the upper midwest: implications for management, Laursen, S.B., and J.F. DeBoe (eds.). Minn. Ext. Serv., Univ. of Minn., St. Paul, MN.

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