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Planting White Oak in the Ozark Highlands: A Shelterwood Prescription

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The shelterwood method can be used to create conditions favorable to regenerating oaks (Dey and Parker 1996, Hannah 1987, Johnson *et al.* 1989, Loftis 1990). Moreover, combining oak planting with the shelterwood method offers an alternative to relying exclusively on natural regeneration (Johnson *et al.* 1986). Shelterwoods of appropriate density can provide planted oaks with sufficient light and time for them to reestablish and expand their root systems before final shelterwood removal (Dey and Parker 1996, 1997). The planted oaks then can successfully compete with other established tree reproduction in the race to capture growing space after the shelterwood is removed. However, the success of the method depends on the size and type of nursery stock that is planted (Johnson 1984). A shelterwood prescription for planting white oak in the Ozark Highlands of southern Missouri and adjacent States is presented below. It is based on the results of an 11-year study of different types of 3-0 seedlings planted under, and subsequently released from, a shelterwood.

Application and Prescription

The prescription calls for:

- Planting on sites with a site index of 60 ft or greater for black oak (*Quercus velutina* Lam.).
- Reducing overstory density to 60 percent stocking based on Gingrich's (1967) stocking chart by thinning from below (i.e., concentrating removals on subcanopy trees down to 2-inches d.b.h.).
- Treating the planting site with an effective herbicide before planting by targeting woody plants between 1/2-inch and 2-inches d.b.h.
- Planting undercut and top-clipped seedlings that have been undercut during their second year in the nursery and that average at least 1/4- to 3/8-inch in caliper measured 1 inch above the root collar.
- Removing the shelterwood after three growing seasons.

The prescription is based on planting seedlings that have been undercut (or optionally not undercut) in the nursery, top-clipped (i.e., shoots cut off) 8 inches above the root collar, and root-pruned 10 inches below the root collar (fig. 1). The prescription requires knowing the average shoot diameter (caliper) of seedlings measured 1 inch above the root collar. This facilitates determining the number

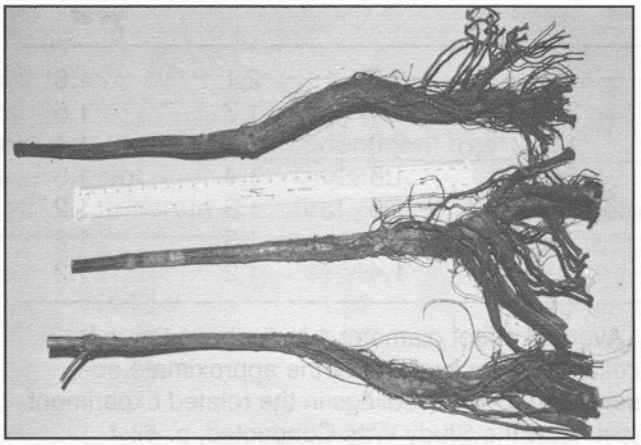

Figure 1.—*White oak seedlings prepared for planting. We recommend top-clipping shoots 8 inches above the root collar and pruning the taproot 10 inches below the root collar. Lateral roots should be appressed to the taproot and pruned at the taproot pruning point. After seedlings are planted, new roots are produced at or near pruning points on the taproot and larger lateral roots.*

of seedlings that must be planted to obtain, on the average, one dominant or codominant tree 8 years after shelterwood removal (11 years after planting). We call these numbers "planting factors" (PF's) (table 1). We define a planted tree as dominant or codominant if it attains at least 80 percent of the mean height of dominant and codominant competitors (11.1 ft) 8 years after shelterwood removal. The predominant arboreal competitors of oaks in regenerating stands in the Ozark Highlands are flowering dogwood (*Cornus florida* L.), sassafras (*Sassafras albidum* (Nutt.) Nees), blackgum (*Nyssa sylvatica* Marsh.), and hickories (*Carya* spp.). Accordingly, if the objective were to obtain 100 dominant and codominant planted trees per acre 8 years after overstory removal, it would be necessary to plant PF x 100 trees per acre.

To create the shelterwood, we recommend thinning stands to 60 percent stocking before planting. Thin by removing trees from the lower crown canopy first and then removing additional trees as necessary (fig. 2). Gingrich's (1967) stocking chart or equation can be used to obtain the correct residual stocking. Our prescription also calls for applying an effective herbicide to woody competitors between 1/2-inch and 2-inches d.b.h. before planting. The herbicide can be optionally reapplied just before shelterwood removal if the understory redevelops after the preparatory cut. Three years after planting, the shelterwood should be completely removed, including all trees 2-inches d.b.h. and larger.

Table 1.—*Number of white oak seedlings required to produce one dominant or codominant tree 8 years after shelterwood removal (planting factor) by initial seedling caliper and nursery undercutting treatment*

	Planting factor (PF)[2]		
Initial seedling caliper (in.)[1]	**Not undercut**	**Undercut first year**	**Undercut second year**
1/4	3.2	2.1	1.8
3/8	2.4	1.7	1.5
1/2	2.0	1.5	1.4
5/8	1.8	1.4	1.3
3/4	1.6	1.3	1.2
7/8	1.5	1.3	1.2
1	1.4	1.2	1.2

[1] Average shoot diameter 1 inch above the root collar. Caliper is given for the approximate observed range of seedlings in the related experiment (see How the Study Was Conducted, p. 4).
[2] Based on 3-year-old seedlings with tops clipped 8 inches above the root collar after lifting and roots pruned to a common length of 10 inches after lifting (fig. 1). For seedlings not undercut: $PF = 1+e\{-(0.8348 + 1.1667 \cdot ln\text{caliper}$; for seedlings undercut the first year: $PF = 1+e\{-(1.5332 + 1.1667 \cdot ln\text{caliper})\}$; for seedlings undercut the second year: $PF = 1+e\{-(1.7938 + 1.1667 \cdot ln\text{caliper})\}$, where caliper is in inches.

Figure 2.—*Planting white oak under a shelterwood thinned from below to 60 percent stocking.*

We recommend spring planting with seedlings that average 1/4- to 3/8-inch in caliper that have been undercut the second year in the nursery and top-clipped before planting. Based on the expected performance of those seedlings, it would be necessary to plant 180 1/4-inch seedlings per acre to obtain 100 competitively successful trees per acre 8 years after shelterwood removal (table 1). If planted seedlings average 1/2-inch in caliper, 140 trees per acre would need to be planted to meet the same goal. The appropriate planting factor for any lot of seedlings can be determined by randomly selecting about 30 seedlings for measurement from among those to be planted. We do not recommend planting seedlings smaller than 1/4-inch in caliper. White oak seedlings 1/4- to 3/8-inch in caliper can be produced in 2 years in nurseries in the Central Hardwood Region. For a given seedling size and nursery treatment, we might expect 2-0 seedlings to perform comparably to the 3-0 seedling reported here. However, we have no comparative data to confirm this. The planting factors presented in table 1 may not be applicable to regions outside the Ozark Highlands. Even within the Ozark Highlands, the planting factors presented may not be applicable where site quality and competition differ appreciably from the study sites.

Although the number of seedlings required to meet a future stocking goal decreases as seedling caliper increases, the performance advantage of seedlings larger than 3/8-inch may not offset their increased cost. Based on our cost estimates and observed range of seedling calipers, it is most cost-effective to plant 1/4- to 3/8-inch seedlings (table 2). For 1/4- or 3/8-inch seedlings, we estimate that it would cost $110 to obtain 100 dominant or codominant trees versus $117 for 1/2-inch seedlings and $136 for 3/4-inch seedlings (exclusive of herbicide, administrative, and other costs not accounted for in table 2). For a seedling of a given initial caliper, the cost of obtaining a dominant or codominant tree is higher for seedlings that are not undercut or undercut the first year only. For seedlings that are not undercut, the most cost-effective size would be 1/2-inch caliper ($168 per 100 dominant and codominant trees) (table 2). Our seedling and planting costs have been estimated by "expert opinion" and remain to be verified operationally. Because these costs are likely to vary greatly from one locale to another and/or over time, the primary value of table 2 may be to illustrate how planting factors can be used to estimate costs and thereby determine the most cost effective size and type of nursery stock. The estimates presented nevertheless point out the importance and utility of specifying the success rate of planted trees expressed as a planting factor. Herbicide treatments and administrative and other costs will add to the costs shown in table 2.

The required number of planted trees will depend on how many oaks are desired in the future stand. Therefore, an appropriate density of planted trees will depend on the expected contribution of oak natural reproduction to the stocking of the future stand and management objectives. For the Ozark Highlands, contributions to future stocking from natural reproduction can be estimated using *ACORn*, a predictive regeneration model (Dey *et al.* 1996b). To minimize planting costs, the minimum number of planted seedlings required to compensate for estimated future deficiencies in the natural oak regeneration potential should be estimated. Such deficiencies must be defined by the silviculturist based on management objectives. However, even without planting, total future stand stocking (oaks plus other tree species) 20 years after shelterwood removal can be expected to be at or near 100 percent regardless of the number of trees that are planted. Planting white oak under shelterwoods therefore provides only reasonable assurance that a specified number of dominant and codominant white oaks are represented in the future stand at a specified future stand age. Site-specific stand dynamics, together with the size and type of seedling that is planted, determine planted tree success.

Applying an effective herbicide to preestablished competition (woody plants 1/2-inch to 2-inches d.b.h.) serves two purposes. First, the treatment removes or reduces the density of a

Table 2.—*Estimated cost of obtaining one dominant or codominant planted tree in relation to initial seedling caliper and undercutting treatment*

Seedling caliper (in.)[1]	Cost of one seedling[2]	Cost of planting one seedling[3]	Cost of seedling + planting	Cost per dominant/codominant tree[4]		
				Not undercut	Undercut first year	Undercut second year
1/4	$0.25	$0.35	$0.60	$1.91	$1.25	$1.10
3/8	0.35	0.38	0.73	1.71	1.22	1.10
1/2	0.45	0.40	0.85	1.68	1.26	1.17
5/8	0.55	0.43	0.98	1.71	1.34	1.26
3/4	0.65	0.45	1.10	1.77	1.43	1.36
7/8	0.75	0.48	1.23	1.85	1.53	1.46
1	0.85	0.50	1.35	1.94	1.64	1.57

[1] Average seedling caliper.
[2] Based on 3-year-old seedlings with tops clipped 8 inches above the root collar after lifting and roots pruned to a common length of 10 inches after lifting (fig. 1). Our cost estimates assume there is no net cost of undercutting. We assume that the modest cost of the undercutting operation is offset by subsequently reduced lifting, handling, bundling, and cold storage costs associated with the reduced average size of seedlings resulting from undercutting.
[3] Does not include site preparation costs.
[4] Cost per successful tree = (seedling + planting cost) x planting factor (from table 1).

vegetative layer that intercepts light. Second, it reduces competition after shelterwood removal. We recommend using an herbicide such as Tordon as a basal spray applied to freshly cut stems the winter before planting. It may be feasible to plant oaks in the Ozark Highlands without the use of herbicides, but this would require subjective upward adjustment of the planting factors presented in table 1. Guidelines for making such adjustments are presented elsewhere (Johnson 1992).

How The Study Was Conducted

We planted 1,280 three-year-old white oak seedlings under a mixed oak stand thinned from below to 60 percent stocking based on Gingrich's (1967) stocking equation. Seedlings were grown in the George O. White State Forest Nursery in Missouri. The planted trees represented 10 seed sources, 5 from Missouri and 5 from Mississippi. Seedlings received one of four undercutting treatments in the nursery: (1) not undercut, (2) undercut during the first growing season, (3) undercut during the second growing season, and (4) undercut during the first and second growing seasons. Seedlings were undercut at a depth of 6 inches during middle to late June after completing one or two flushes of shoot growth. Those undercut the second year were undercut at a depth of 8 inches. After either fall lifting in November 1984 or spring lifting in early March 1985 and before planting, half the seedlings in each undercutting treatment were top-clipped 8 inches above the root collar. Taproots and lateral roots of all seedlings were pruned to a common length of 10 inches below the root collar after lifting (fig. 1). The initial caliper (basal diameter measured 1 inch above the root collar) of each seedling was measured to the nearest 0.1 inch and recorded.

In April 1985 we outplanted the seedlings on two sites on the Sinkin Experimental Forest in southern Missouri, which lies within the Central Plateau Subsection of the Ozark Highlands as defined by McNab and Avers (1994). Planting sites were dominated by black oak and white oak (*Q. alba* L.); site index for black oak ranged from 62 to 65 ft at an index age of 50 years based on McQuilkin's (1974) site index table. All woody stems between 1/2-inch and 2-inches d.b.h. and all stumps created by the shelterwood preparatory cut were treated with an herbicide (Tordon RTU) before planting. After three growing seasons, the shelterwood was completely removed during the winter of 1987-1988. Stumps created by the final shelterwood removal also were treated with the herbicide. Planted tree heights and survival were measured and recorded annually or biannually for 11 years. The heights of dominant competitors were also measured in 1990, 1992, 1993, and 1995 (6, 8, 9, and 11 years after planting, respectively). The tallest woody competitor within a 3.3-foot radius of every fourth planted tree was measured to facilitate calculating the mean height of dominant and codominant competitors on the study area.

Results and Discussion

Survival of planted oaks ranged from 100 percent at the end of the first field growing season to 40 to 85 percent at the end of the 11th growing season, depending on treatment. Survival rates decreased rapidly from 1985 through 1987 as small trees succumbed to suppression. Survival was lowest for seedlings that were neither undercut nor top-clipped declining to 40 percent by 1995. Survival in the other treatments ranged from 68 to 85 percent by 1995.

Mean heights of survivors also differed appreciably by treatments over the study period. Dieback of planted trees that were not top-clipped showed no net gain in height during the first 5 years, of which planted trees were under the shelterwood for 3 years. In contrast, top-clipped trees averaged 14 inches in net height growth during the same period. Planted trees that were top-clipped and undercut the second year grew more than 13 feet in height during the 8 years after shelterwood removal. This growth was sufficient to maintain the average heights of surviving planted trees at or above 80 percent of the average heights of dominant competitors (11.1 ft in 1995).

Planted tree performance based on mean heights of survivors potentially conceals information on the effects of initial seedling size and the distribution of heights. For that reason, we used logistic regression analysis to estimate the probability that a seedling of a given nursery treatment and initial caliper will equal or exceed 80 percent of the mean height of dominant competitors 8 years after shelterwood removal. We call the resulting estimates *dominance probabilities* because they express the likelihood that a planted tree of a given treatment and initial caliper will be competitively successful. These probabilities thus integrate survival and growth into a single value that is silviculturally useful.

Results of the logistic regression analysis show that seedling caliper, undercutting, and top-clipping all significantly influence estimated dominance probabilities. Time of lifting (spring vs. fall) had no

significant effect on the estimates. Seed source effects were not tested. Within each undercutting/ top-clipping category, the estimated probability that a seedling attains dominance or codominance rapidly increases with increasing initial seedling caliper. Probabilities range from less than 0.2 for seedlings of 0.2-inch caliper to more than 0.8 for seedlings of 1-inch caliper. For a given initial caliper, top-clipped seedlings undercut the second year or the first and second years have the largest dominance probabilities. Seedlings that are not undercut and not top-clipped have the smallest probabilities (fig. 3). Within a given undercutting treatment, dominance probabilities for a given initial caliper are larger for top-clipped seedlings than for unclipped ones. Although undercutting always resulted in a significant increase in dominance probabilities, probabilities for seedlings undercut the second year or both first and second years were nominally larger than seedlings undercut the first year. Because dominance probabilities for seedlings undercut the second year and seedlings undercut the first and second years were nearly identical, we combined seedlings from those treatments into a single group in the final predictive model. The reciprocals of the estimated dominance probabilities are the planting factors presented in table 1.

Initial seedling caliper is a useful predictor of a seedling's chance of attaining dominance or codominance because it is correlated with seedling root mass. In turn, root mass and associated capacity for root extension are important physiological determinants of the growth of oak reproduction (Dey *et al.* 1996a, Johnson 1979). Undercutting (or transplanting) seedlings in the nursery stimulates the formation of large lateral roots and thus the number of sites from which new roots can develop after planting (Johnson 1988, Johnson *et al.* 1984). The beneficial effects of top-clipping are less well understood. However, in northern red oak, top-clipping had no measurable effect (positive or negative) on the performance of trees planted in clearcuts. But when trees were planted under shelterwoods, there was a significant beneficial effect (Johnson 1984). This suggests that shoots of large, unclipped seedlings are sinks for the modest amounts of carbohydrates produced under the relatively low light conditions beneath shelterwoods. Top-clipped seedlings therefore may direct proportionately more photosynthate to expanding their root systems. Thus, when the shelterwood is removed, the benefit of a large root system is expressed through rapid shoot growth. This theory is consistent with the root-centered regeneration strategy of oaks (Johnson 1993). Top-clipping is also beneficial to the success of other planted hardwoods (South 1996).

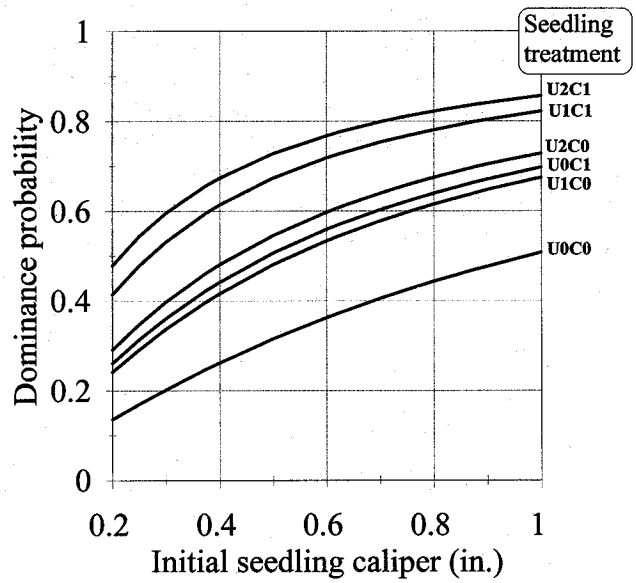

Figure 3.—*Dominance probabilities for planted white oaks in relation to initial seedling caliper, undercutting, and shoot clipping treatments. Seedling treatments: U0C0 = not undercut, not top-clipped; U0C1 = not undercut, top-clipped; U1C0 = undercut first year, not top-clipped; U1C1 = undercut first year, top-clipped; U2C0 = undercut second year or first and second years, not top-clipped; U2C1 undercut second year or first and second years, top-clipped. Dominance occurs when a planted tree attains at least 80 percent of the expected mean height of dominant and codominant competitors (11.1 ft) 8 years after complete shelterwood removal.* $P=1/\{1 + e[-(0.0326 + 1.1667 \cdot \ln CAL + 0.6984Ua + 0.9590 \cdot Ub + 0.8022 \cdot C)]\}$, *where P = dominance probability, CAL = initial seedling caliper (in.), Ua = 1 if seedlings are undercut the first year (otherwise Ua = 0), Ub = 1 if seedlings are undercut the second year or the first and second years (otherwise Ub = 0), C = 0 if seedlings are not top-clipped, and C = 1 if seedlings are top-clipped.*

The study results are generally consistent with similarly derived dominance (or "success") probabilities reported for other oak planting studies in the Ozark Highlands (Johnson 1984, 1988; Johnson *et al.* 1986; Weigel and Johnson 1998), and further confirm the biological advantages of shoot clipping, undercutting, and large initial seedling size when seedlings are planted under shelterwoods.

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