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Planting Northern Red Oak in the Ozark Highlands: A Shelterwood Prescription

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The shelterwood method can be used to create the conditions necessary for regenerating northern red oak (*Quercus rubra* L.) (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 provide planted oaks with sufficient light while allowing the necessary time for them to reestablish and expand their root systems before final harvest (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 northern red oak in the Ozark Highlands of southern Missouri and adjacent States is presented below. It is based on the results from a 13-year study of different types of 2-0 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 2-year-old seedlings with clipped tops that average at least 1/4-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

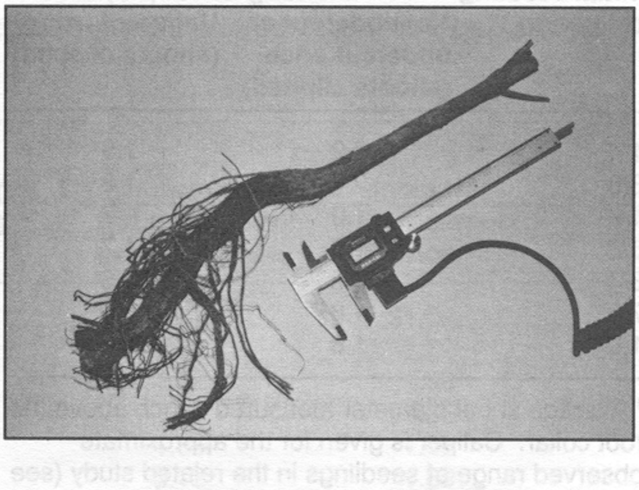

Figure 1.—*A 2-year-old northern red oak seedling prepared for planting. We recommend top-clipping shoots 8 inches above the root collar and pruning the taproot and laterals 10 inches below the root collar. Lateral roots should be appressed to the taproot and pruned at the taproot pruning point. After planting, 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 10 years after shelterwood removal (13 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 (9.6 ft) 10 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 10 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. Thinning should be done by removing trees from the lower crown canopy first and then removing additional trees as necessary (fig. 2).

Table 1.—*Number of planted seedlings required to produce one dominant or codominant tree 10 years after overstory removal (planting factor) by initial seedling caliper and undercutting treatment*

Initial seedling caliper (in.)[1]	Planting factor (PF)[2]	
	Not undercut or undercut once (shoots clipped)	Undercut twice (shoots clipped)
1/4	2.2	1.9
3/8	2.0	1.8
1/2	1.9	1.7
5/8	1.8	1.7
3/4	1.8	1.6
7/8	1.8	1.6
1.0	1.8	1.6

[1] Average shoot diameter measured 1 inch above the root collar. Caliper is given for the approximate observed range of seedlings in the related study (see How the Study Was Conducted, p. 4).

[2] Based on 2-year-old seedlings with tops clipped 8 inches above the root collar after lifting and roots pruned to a common length of 10 inches before planting (fig. 1). For seedlings undercut years 1 and 2 in the nursery: PF = 1 + e{-(0.5428 + 0.3233•*ln*caliper)}.
For seedlings not undercut or undercut the first year in the nursery: PF = 1 + e{-(0.2844 + 0.3233•*ln*caliper)}.

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

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.

We recommend planting in the spring with seedlings that are at least 1/4-inch in caliper that have been undercut both years in the nursery and top-clipped before planting. Based on table 1, it would be necessary to plant 190 such seedlings averaging 1/4-inch in caliper to obtain 100 competitively successful trees 10 years after shelterwood removal (fig. 3). If seedlings averaged 1/2-inch in caliper, 170 trees 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. 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 planted seedlings required to meet a specified goal decreases as seedling caliper increases, the advantage of large size may not offset the increased cost of growing larger seedlings. Based on our cost estimates and observed range of seedling calipers, it is most cost-effective to plant 1/4-inch seedlings (table 2).

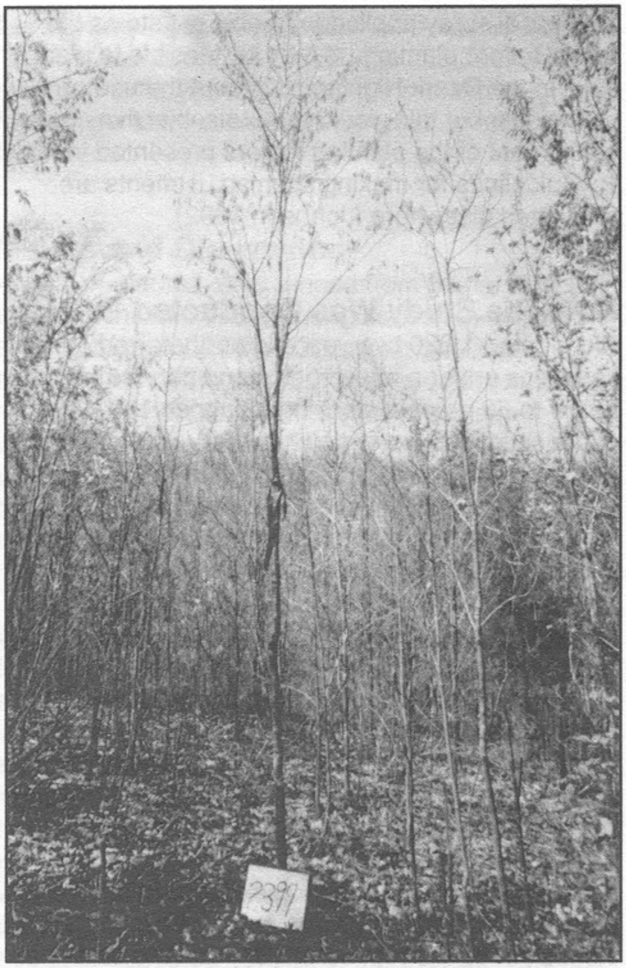

Figure 3.—*This planted red oak was 17 feet tall and in a dominant crown position 13 years after planting (10 years after shelterwood removal). If the planting prescription is followed, about 53 percent of top-clipped and twice-undercut 2-0 seedlings that are 1/4-inch in caliper can be expected to attain dominance or codominance at this stand age.*

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 or undercut once	Undercut twice
1/4	$0.20	$0.35	$0.55	$1.21	$1.04
3/8	0.30	0.38	0.68	1.36	1.22
1/2	0.40	0.40	0.80	1.52	1.36
5/8	0.50	0.43	0.93	1.67	1.58
3/4	0.60	0.45	1.05	1.89	1.68
7/8	0.70	0.48	1.18	2.12	1.89
1.0	0.80	0.50	1.30	2.34	2.08

[1] Average seedling caliper.
[2] Based on 2-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 dominant or codominant tree = (seedling + planting cost) x planting factor (from table 1).

Obtaining 100 dominant or codominant trees would cost $104 for 1/4-inch seedlings versus $136 for 1/2-inch seedlings (exclusive of herbicide, administrative, and other costs not accounted for in table 2). For seedlings that are not undercut or once-undercut, the cost of obtaining 100 dominant or codominant increases to $121 for seedlings 1/4-inch in caliper and $152 for seedlings 1/2-inch in caliper.

Although our nursery stock and planting costs have been estimated by "expert opinion," they 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. This will depend, in part, on the expected contribution of oak natural reproduction to 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 developed by Dey and others (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. 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 northern red oak in shelterwoods therefore provides only reasonable assurance that a specified number of dominant or codominant red oaks are represented in the future stand at a specified future stand age. Site-specific stand dynamics, together with seedling size and physiological quality, 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 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 1,920 two-year-old northern red oak seedlings under a mixed oak stand thinned from below to 60 percent stocking (Gingrich 1967). Half of the seedlings were grown in the Vallonia State Forest Nursery in Indiana and half in the George O. White State Forest Nursery in Missouri. The planted trees represented 10 seed sources, 5 from Missouri and 5 from Indiana. Seedlings received one of three undercutting treatments in the nursery bed: (1) not undercut (U0), (2) undercut during the first growing season (U1), and (3) undercut during the first and second growing seasons (U2). 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 spring lifting in early April 1984 and before planting, the tops of half the seedlings in each undercutting treatment were cut off ("clipped") 8 inches above the root collar (C1) and the other half were left intact (C0). Taproots and lateral roots of all seedlings were pruned to a common length of 10 inches below the root collar (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 1984, we outplanted the seedlings 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). The site was dominated by black oak and white oak (*Q. alba* L.); black oak site index was 62 ft at an index age of 50 years based on McQuilkin's (1974) site index table. Seedlings were planted at a spacing of 3.3 x 3.3 feet in a randomized block design with eight replications. All woody stems between 1/2-inch and 2-inches d.b.h. and all stumps created by the shelterwood cut were treated with an herbicide (Tordon RTU) before planting. After three growing seasons, the shelterwood was completely removed during the winter of 1986-1987. Stumps created by the final overstory removal also were treated with the herbicide. Planted tree heights and survival were measured and recorded annually for the first 8 years and at year 13. The heights of dominant competitors also were measured 7, 8, and 13 years after planting. 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 98 percent at the end of the first field growing season to 50 to 77 percent at the end of the 13th growing season, depending on treatment. Survival rates decreased sharply from 1984 to 1987 as small trees succumbed to suppression. Survival was lowest for seedlings in treatment U0C0, which declined to 50 percent by 1996. Survival in the other treatments ranged from 57 to 77 percent by 1996.

Mean heights of survivors also differed appreciably by treatments over the study period. Dieback of trees in the C0 treatments resulted in negative height growth during the first 4 years, during which planted trees were under the shelterwood for 3 years. In contrast, C1 trees averaged 7 to 10 inches in net height growth during the same period. The planted trees in the best treatment grew more than 11 feet in height during the 10 years after overstory 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 (9.6 ft in 1996).

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 initial shoot size (caliper) will equal or exceed 80 percent of the mean height of dominant competitors 10 years after shelterwood removal. We call the resulting values *dominance probabilities* because they express the likelihood that a planted seedling of a given treatment and initial caliper will be dominant or codominant. These probabilities thus integrate survival and growth into a single value that is silviculturally useful.

Results of the logistic regression analysis show that, within each treatment group, the likelihood of a planted tree attaining dominance or codominance increases with increasing initial seedling caliper. Probabilities range from less than 0.4 for seedlings 0.2 inch in initial caliper to more than 0.6 for seedlings 1 inch in caliper (fig. 4). Because dominance probabilities of trees in U0 and U1 treatments did not differ statistically in 1996 (P<0.05), they were

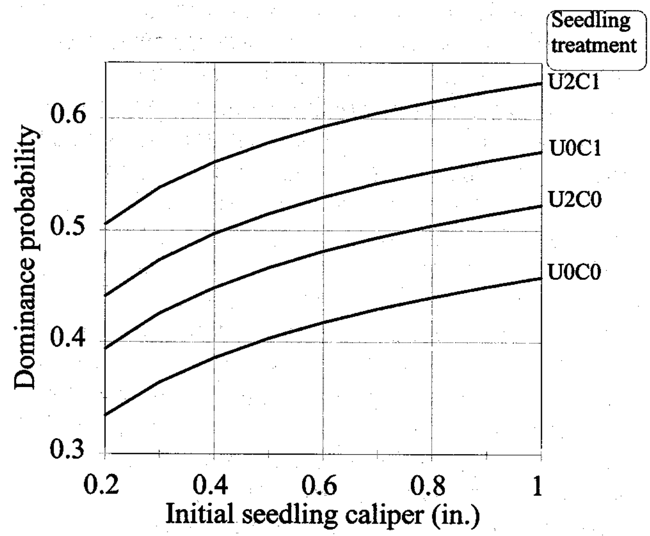

Figure 4.—*Estimated dominance probabilities for planted northern red oak in relation to initial seedling caliper and undercutting (U) and shoot clipping (C) treatments. Dominance is deemed to occur when a planted tree attains at least 80 percent of the expected mean height of dominant and codominant competitors (9.6 ft) 10 years after complete shelterwood removal. P=1/{1+e[-(- 0.1676 + 0.3233•lnCAL + 0.2584•U + 0.4520•C)]}, where P = dominance probability, CAL = seedling shoot caliper (in.), U = 0 if seedling is not undercut or is undercut the first year, U = 1 if undercut both years, C = 0 if seedling is not top-clipped, and C = 1 if top-clipped. Thus, seedling treatment U2C1 refers to a top-clipped seedling that was undercut both years, U0C0 to an unclipped seedling that was not undercut or was undercut year 1, etc.*

combined and designated U0 to signify no undercutting effect. For a given initial caliper, largest estimated dominance probabilities occur in treatment U2C1 and smallest probabilities occur in treatment U0C0. Within a given undercutting treatment group, dominance probabilities for a given initial caliper are larger for clipped than for unclipped seedlings. Planting factors (table 1) are thus the reciprocals of the dominance probabilities. They express the number of planted seedlings needed to obtain, on the average, one dominant or codominant tree 10 years after overstory removal.

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) (fig. 5). The beneficial effects of top-clipping are less well understood. However, in northern red oak, top-clipping had no measureable 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).

The study results are generally consistent with similarly derived dominance (or "success") probabilities reported from 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 seedling caliper when seedlings are planted under shelterwoods.

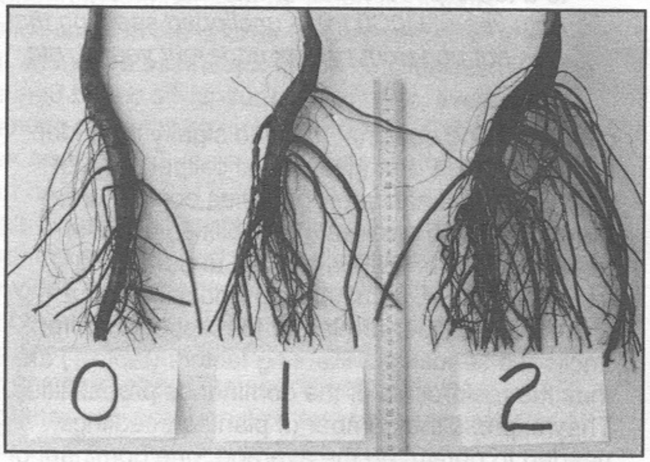

Figure 5.—*Undercutting 2-year-old northern red oak seedlings in the nursery increases the number of large lateral roots from which new roots originate after planting. Representative seedlings from three treatments are shown: (0) not undercut, (1) undercut once (year 1), and (2) undercut twice (years one and two).*

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Pesticide Precautionary Statement

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