
Oak Regeneration Potential Increased by Shelterwood Treatments

Richard C. Schlesinger, Ivan L. Sander, and Kenneth R. Davidson, *USDA Forest Service, North Central Forest Experiment Station, 1-26 Agriculture Bldg., Univ. of Missouri, Columbia, MO 65211.*

ABSTRACT. *In much of the Central Hardwood Forest Region, oak species are not regenerating well, even though large oak trees are common within the existing forests. The shelterwood method has been suggested as a potential tool for establishing and developing advanced regeneration where it is lacking. The 10-yr results from a study of several variants of the shelterwood method show that on good sites in the Missouri Ozarks Region, a heavy understory treatment is most important, while on average sites, reducing the overstory density level is most important. The right combinations of overstory and understory treatments will likely be different for different stands and locations, but the shelterwood method does appear to be a useful silvicultural tool for perpetuating central hardwood oak forests. North. J. Appl. For. 10(4): 149–153.*

Within much of the Central Hardwood Forest Region, there is longstanding concern that oak species are not regenerating well, and that many of the forests now dominated by oaks will be dominated by other species and species groups in the future (Sander 1988, Lorimer 1989). Although such change is not necessarily bad, the various oak species are considered important components of the forests, providing wood products, food for wildlife, and variety to the landscape.

Advanced oak regeneration has long been recognized as the key to maintaining the oak component in central hardwood forests (Carvell and Tryon 1961), but how to obtain sufficient amounts of advanced regeneration where it is not present has been less obvious. Several people have suggested that the shelterwood regeneration system may be an effective method for doing so (Clark 1970, Sander 1979). We conducted a study to test several variants of the shelterwood method for increasing the oak regeneration potential on sites where oak reproduction is not sufficient to meet regeneration goals.

Methods

The study area is located in the heart of the Missouri Ozarks (lat.37.5°N, long.91.3°W) on the Sinkin Experimental Forest. The soils in the area are predominantly Clarksville stony or gravelly loams (loamy-skeletal, siliceous, mesic, Typic Paleudults). There were 30 treatment plots on each of two site classes. The treatment plots were 1.04 ac in size with a 0.3 ac measurement plot in the center. The mean black oak site index (height in feet at 50 yr) for the 30 average site plots

was about 60, while the mean site index for the 30 good site plots was about 75.

The primary oak species on the study areas were white oak, black oak, northern red oak, and scarlet oak. Post oak, present in small numbers, was included with the less desirable tree species. Other overstory species included black gum, hickory (mainly shagbark and mockernut), and red maple. The primary understory species were dogwood and sassafras.

Three overstory density treatments [leaving 40, 50, or 60% stocking based on the oak-hickory stocking equation (Gingrich 1967)] were combined factorially with three understory treatments (heavy, medium, or none) and replicated within three blocks on each site class. In addition, controlled burning was tested as an understory treatment at 50% overstory stocking. The controlled burning treatment consisted of two burns, one in the spring immediately after the overstory treatment and a second 3 yr later. Thus, there were 10 distinct shelterwood treatments.

These treatments were slightly different for the two site classes. In both cases, the overstory leave trees were primarily the larger, more vigorous oaks, and the overstory treatment removed trees down to 1.6 in. dbh. On the good site, the cut stumps of nonoak species were treated with herbicide to reduce sprouting. On the average site, all stumps including oak stumps were treated with herbicide to reduce sprouting. The objective of the heavy understory treatment was to kill all woody vegetation less than 1.6 in. dbh except oaks on the good site, and it included oaks taller than 3 ft on the average site. The medium understory treatment was designed to kill

all woody vegetation taller than 6 ft and less than 1.6 in. dbh on the good site, and it included oaks taller than 6 ft on the average site. The third understory treatment left all woody vegetation on both sites.

Seed production was measured annually during the first 3 yr after treatment. There were 10 seed traps in each of 3 plots within each overstory density level, for a total of 30 samples per overstory density level per site. The traps had a surface collecting area of 3.25 ft². The acorns were examined to determine if they were mature and sound.

Reproduction was measured on twenty 1/735-ac subplots within each main plot. The subplots were measured before treatment, 1 or 2 yr after treatment (average and good sites, respectively), and 10 yr after treatment. Measurements included a complete tally of all stems by species and 0.305 ft height classes. In addition, all oak stems and a sample of stems of other species were identified and mapped so they could be remeasured. For these stems, height and stem diameter 1 in. above the ground were measured to the nearest 0.4 in. and 0.04 in., respectively.

Analysis of variance and covariance was used to examine the response of the reproduction to the treatments. Because the treatments were not identical on the two sites, each site was analyzed separately. The response variables of primary interest were the numbers of large (taller than 4.5 ft) oak reproduction after 10 yr and the change in numbers during the 10-yr period. Regeneration stocking values were computed using the method of Sander et al. (1984) and were also analyzed with analysis of variance and covariance.

The analyses were run separately for the 3 × 3 factorial involving the overstory and understory treatments and for the four understory treatments (including controlled burning) at an overstory density of 50% stocking. The latter analyses used some of the same plots as the 3 × 3 factorial analyses and are thus not completely independent.

Analyses of the data collected before the shelterwood treatments were applied indicated significant differences among plots in the numbers of large oak reproduction and stocking values on the good site before treatment, but not on the average site. Therefore, analyses of covariance were used for the good site data, with the original number of large oak reproduction (or stocking value) as the covariate. Analyses of variance were used for the average site data.

Results and Discussion

The analyses using regeneration stocking values and those using numbers of large oak reproduction yielded the same conclusions about treatment effects. Because the stocking value calculations may not be appropriate for small treatment plots because the procedure was developed for larger stands, we present only the results based on the large oak reproduction.

Good Site

Based on the analysis of covariance, the absolute number of large oak saplings per acre after 10 yr was significantly affected by the understory treatment, especially the most

intensive understory treatment (Table 1). The overstory stocking level did not significantly affect the numbers of saplings. The number of saplings increased by 221 stems within the heavy understory treatment plots compared to increases of 114 and 110 stems within the medium and control treatments, respectively.

The heavy understory treatment was about twice as effective as the other two treatments in increasing the number of large oak saplings. However, if 435 stems per acre 4.5 ft tall or taller are necessary to provide adequate regeneration (Sander et al. 1976), not even the best treatment combination, the heavy understory treatment at 60% stocking, met this goal.

For the understory (dogwood and sassafras) and shrub (primarily witchhazel) species combined, the lowest stocking level favored the development of more large saplings (Table 2). On the other hand, there were fewer large saplings within the plots that received the heavy initial understory treatment. Thus, the best combination for minimizing competition from these species was the most intensive understory treatment and the highest overstory density.

Initially, the oak saplings were only 2.8% of all large reproduction stems (Table 3), ranging from 0 to 26.9% on the 27 individual plots. Sixteen of the plots had no oak saplings. The understory species (mainly dogwood and sassafras) made up 69.8% of the saplings. At the end of 10 yr, oaks had increased to 5.5% of the large saplings, and understory species had decreased to 61.5%. And within the heavy understory treatment, the oaks made up 10% of the large saplings, and the understory species made up 55.2%. During the first 3 yr following treatment, there were 142,000, 201,000, and 169,000 sound acorns per acre produced under the 40%, 50%, and 60% overstory densities, respectively.

The covariance analysis for the 4 understory treatments including controlled burning showed a significant treatment effect. The number of large saplings at the end of 10 yr was 295 and 250 on the burned and heavy understory treatment plots, respectively, but was only 163 and 127 on the control and medium understory treatment plots, respectively.

Average Site

The heavy understory treatment reduced the number of large oak saplings from 151 to 0, the medium treatment from 135 to 12, and the control treatment from 82 to 74. Since the understory treatments reduced the large oaks by different amounts, the changes in numbers from immediately after treatment are of primary interest because they reflect the response of the remaining oak reproduction to the shelterwood treatments.

The analysis of variance for the 10 yr data showed no significant understory treatment effects (Table 4), but a significant overstory effect. The lowest stocking level resulted in the most large oak regeneration. An analysis of the change in numbers from immediately after treatment until the 10th year showed the same result. For the average site, the numbers per acre for the lowest stocking level exceed the suggested number of 435/ac thought to be sufficient to provide the oak component in the next stand.

Table 1. Number per acre of large oak reproduction stems 10 yr after treatment and () before treatment, good site only.

Understory removal treatment	Overstory treatment Residual stocking level							
	40%		50%		60%		All levels ^a	
Heavy	306	(37)	208	(0)	343	(159)	286 a	(65)
Medium	208	(37)	98	(12)	86	(0)	130 b	(16)
Control	86	(0)	172	(49)	184	(61)	147 b	(37)
All removals ^a	200 a	(25)	159 a	(20)	204 a	(73)	188	(39)

^aMeans followed by the same letter are not significantly different according to Duncan's Multiple Range Test.

Table 2. Number per acre of large understory species (dogwood, sassafras, and shrub) reproduction stems 10 yr after treatment, good site only.

Understory removal treatment	Overstory treatment Residual stocking level							
	40%		50%		60%		All levels ^a	
Heavy	2377		1764		600		1580b	
Medium	2671		2744		1936		2450a	
Control	2658		1838		2242		2246a	
All removals ^a	2569a		2115a b		1593b		2092	

^aMeans followed by the same letter are not significantly different according to Duncan's Multiple Range Test.

Table 3. Percentage of large reproduction stems that were oaks 10 yr after treatment and () before treatment, good site only.

Understory removal treatment	Overstory treatment Residual stocking level							
	40%		50%		60%		All levels ^a	
Heavy	7.6	(3.8)	6.7	(0.0)	23.7	(16.9)	10.0	(5.8)
Medium	4.8	(2.3)	2.6	(1.0)	2.7	(0.0)	3.5	(1.2)
Control	2.6	(0.0)	4.8	(2.7)	4.9	(3.5)	4.1	(2.2)
All removals ^a	5.1	(1.9)	4.5	(1.4)	7.3	(5.3)	5.5	(2.8)

Table 4. Number per acre of large oak reproduction stems 10 yr after treatment and () immediately after treatment, average site only.

Understory removal treatment	Overstory treatment Residual stocking level							
	40%		50%		60%		All levels ^a	
Heavy	588	(0)	306	(0)	74	(0)	323 a	(0)
Medium	576	(25)	294	(12)	306	(0)	392 a	(12)
Control	527	(135)	441	(49)	319	(37)	429 a	(74)
All removals ^a	564 a	(53)	347 b	(20)	233 b	(12)	381	(29)

^aMeans followed by the same letter are not significantly different according to Duncan's Multiple Range Test.

There were fewer large saplings of the understory species on the average site than on the good site: 329/ac versus 976 (before treatment) and 828 versus 2092 (10 yr after treatment). The number of saplings 10 yr after treatment was not significantly affected by either the understory treatment or the overstory treatment (Table 5).

The combination of more large oak saplings and fewer large saplings of the understory species resulted in a higher proportion of large oak saplings on the average site than on the good site (Table 6). On the average site, the oaks made up 15% of the large saplings before treatment and 19% 10 yr after treatment. Before treatment, only 1 of the 27 average site plots had no large oak reproduction. On this site, sound acorn production during the first 3 yr following treatment was 130,000, 145,000, and 160,000/ac for the 40%, 50%, and 60% overstory density levels, respectively.

The analysis of the understory treatments including controlled burning showed no significant treatment effects. On the average site, there were 441 large oak saplings per acre after 10 yr for the control treatment, 380 for the controlled burning treatment, 307 for the heavy understory treatment, and 294 for the medium understory treatment. On this site, controlled burning did not benefit the regeneration but did damage a number of the residual overstory trees.

The role of advanced reproduction in the oak regeneration process is well known (Sander and Clark 1971). The shelterwood method has been suggested as a procedure for obtaining enough advanced reproduction to regenerate the oak component in stands where it is insufficient, but the method has frequently failed (Sander 1979). Its primary drawback is that creating the appropriate conditions for oaks

is likely to create excellent growing conditions for competing species. Where the shelterwood method has succeeded, an appropriate mix of overstory opening and understory treatments has been found (Loftis 1990, Wolf 1988).

One key to obtaining an adequate oak component is to have enough advanced reproduction stems of sufficient size that they can compete successfully with the nonoak reproduction following overstory removal. "Enough" has been defined as 435 stems/ac if an oak-dominated stand is the management objective (Sander et al. 1976), but could be less if a smaller oak component in the next stand is acceptable. "Sufficient size" has been defined as about 4.5 ft or larger (Sander 1972).

A second key to successful regeneration is for the oak reproduction stems to be able to compete with other tree and shrub regeneration (Sander et al. 1984, Dey et al. 1991). The competitiveness of an oak regeneration stem depends on both the absolute size of the oak and its size relative to the competing trees and shrubs (Sander 1972).

In the Appalachians, Loftis (1990) found that reducing stand density from below using herbicides was effective for regenerating northern red oak. Furthermore, he found that the better the site quality, the higher the shelterwood stocking level to leave. For the two site classes studied in Missouri, our data support this same general conclusion for mixed oak regeneration. On the better site, the highest stocking level combined with a heavy understory treatment appeared to be most successful, while on the poorer site, the lowest stocking level was best.

Fire is thought to be an important factor in providing a competitive advantage for oak species in Midwest ecosys-

Table 5. Number per acre of large regeneration stems of understory (dogwood, sassafras, and shrub) species 10 yr after treatment, average site only.

Understory removal treatment	Overstory treatment Residual stocking level			
	40%	50%	60%	All levels ^a
Heavy	931	809	478	739
Medium	906	1176	380	821
Control	1078	931	760	923
All removals ^a	972	972	539	828

Table 6. Percentage of large reproduction stems that were oaks 10 yr after treatment and () before treatment, average site only.

Understory removal treatment	Overstory treatment Residual stocking level							
	40%		50%		60%		All levels ^a	
Heavy	25.3	(23.1)	16.3	(14.1)	5.6	(15.0)	17.5	(17.7)
Medium	25.4	(22.2)	11.8	(10.3)	22.7	(14.9)	19.3	(15.5)
Control	19.5	(7.9)	22.2	(19.5)	18.1	(13.4)	19.9	(11.8)
All removals ^a	23.2	(17.2)	16.4	(13.4)	15.8	(14.5)	19.0	(15.2)

tems (Crow 1988, Rouse 1986, Reich et al. 1990). The controlled burning regime tested in this study was as effective as the heavy understory treatment on the better site. We probably did not, and perhaps cannot, duplicate the effects of wildfires by using controlled burning, but we can suggest controlled burning could be a useful regeneration tool on some sites where understory control is needed.

Management Implications

On average sites in the Missouri Ozarks (black oak SI of 55 to 65), numbers of advanced oak reproduction will often be adequate. Simply reducing the overstory density will allow this advanced reproduction to develop so that the oak saplings can compete successfully once fully released. On these sites, there are fewer nonoak species that can compete successfully with the oaks. If the primary management objective is retention of an oak component within the next stand, the final overstory removal cut could be made at ten years, and perhaps earlier.

However, on the better sites (black oak SI 70 and above), reducing the overstory density alone may not be sufficient to produce competitive oak advanced regeneration. It may be necessary to reduce the numbers of competing nonoak saplings directly with fire or herbicide and to retard the development of the competition by maintaining a denser overstory. Furthermore, it appears that developing adequate oak advanced regeneration will require more than 10 yr and/or additional understory treatment.

Adapting the shelterwood system to the regeneration needs of the oaks seems to be quite possible, although a universal system for all sites is not likely. Obtaining advanced oak regeneration of sufficient size and in sufficient numbers to perpetuate this important forest species may require a series of both understory and overstory treatments on the better sites; increasing the radiation within the seedling space may be all that is needed on lower quality sites. But as this, and other, research has shown, some variant of the shelterwood system can be effective for developing the type

and amount of advanced oak regeneration needed on a variety of sites.

Literature Cited

- CARVELL, K.L., and E.H. TRYON. 1961. The effect of environmental factors on the abundance of oak regeneration beneath mature oak stands. *For. Sci.* 7:98-105.
- CLARK, F.B. 1970. Measures necessary for natural regeneration of oaks, yellow-poplar, sweetgum, and black walnut. USDA For. Serv. Res. Pap. NE-144. P. 1-16.
- CROW, T.R. 1988. Reproductive mode and mechanisms for self-replacement of northern red oak (*Quercus rubra*)—a review. *For. Sci.* 34:19-40.
- DEY, D., P.S. JOHNSON, H.E. GARRETT, and P.L. SPECKMAN. 1991. Interfacing a regeneration model with growth and yield models. USDA For. Serv. Gen. Tech. Rep. SE-70. P. 221-228.
- GINGRICH, S.F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the Central States. *For. Sci.* 13:38-53.
- LOFTIS, D.L. 1990. Predicting post-harvest performance of advance red oak reproduction in the southern Appalachians. *For. Sci.* 36:908-916.
- LORIMER, C.G. 1989. The oak regeneration problem: New evidence on causes and possible solutions. *For. Res. Anal.* R3484 No. 8. Univ. Wisc. Sch. Natur. Resour. 31 p.
- REICH, P.B., M.D. ABRAMS, D.S. ELLSWORTH, E.L. KRUGER, and T.J. TABONE. 1990. Fire affects ecophysiology and community dynamics of central Wisconsin oak forest regeneration. *Ecology* 71:2179-2190.
- ROUSE, C. 1986. Fire effects in northeastern forests: Oak. USDA For. Serv. Gen. Tech. Rep. NC-105. 7 p.
- SANDER, I.L. 1971. Height growth of new oak sprouts depends on size of advance reproduction. *J. For.* 69:809-811.
- SANDER, I.L. 1972. Size of oak advance reproduction: Key to growth following harvest cutting. USDA For. Serv. Res. Pap. NC-79. 6 p.
- SANDER, I.L. 1979. Regenerating oaks with the shelterwood system. P. 54-60 in *Regenerating oaks in upland forests*, Holt, H. (ed.). The 1979 John S. Wright For. Conf. Proc. Purdue University, W. Lafayette, IN.
- SANDER, I.L. 1988. Guidelines for regenerating Appalachian oak stands. P. 189-198 in Smith, H.C., A.W. Perkey, and W.E. Kidd, Jr. (eds.). Workshop proc.: Guidelines for regenerating Appalachian hardwood stands. SAF Publ. 88-03. Soc. Am. For., Bethesda, MD.
- SANDER, I.L., and F.B. CLARK. 1971. Reproduction of upland hardwood forests in the Central States. USDA For. Serv. Agric. Handb. 405. 25 p.
- SANDER, I.L., P.S. JOHNSON, and R.F. WATT. 1976. A guide for evaluating the adequacy of oak advance reproduction. USDA For. Serv. Gen. Tech. Rep. NC-23. 7 p.
- SANDER, I.L., P.S. JOHNSON, and R. ROGERS. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. USDA For. Serv. Res. Pap. NC-251. 16 p.
- WOLF, W.W., JR. 1988. Shelterwood cutting to regenerate oaks—the Glatfelter experience. P. 210-218 in Smith, H.C., A.W. Perkey, and W.E. Kidd, Jr. (eds.). Workshop proc.: Guidelines for regenerating Appalachian hardwood stands. SAF Publ. 88-03. Soc. Am. For., Bethesda, MD.