Pine

A Shelterwood-Burn Technique for Regenerating Productive Upland Oak Sites in the Piedmont Region

Patrick H. Brose, *USDA Forest Service, Southern Research Station, Clemson University, Clemson, SC 29634,* **David H. Van Lear,** *Clemson University, Department of Forest Resources, Clemson, SC 29634, and* **Patrick D. Keyser,** *Westvaco Corporation, Rupert, WV 25984.*

ABSTRACT: Regenerating oak stands on productive upland sites is widely recognized by foresters as a major problem in hardwood management. Recent research indicates that oak regeneration is more resistant to surface fires than its primary competitors on these sites if burning occurs 3 to 5 yr after a partial overstory harvest. This combination of cutting followed by fire (shelterwood-burn technique) mimics natural disturbances that have occurred in eastern North America for millennia and appears to be a viable approach to regenerating oaks on productive upland sites. This paper presents silvicultural guidelines for applying the shelterwood-burn technique on productive upland sites and discusses its benefits for private landowners and resource professionals. South. J. Appl. For. 16(3):158–163.

Throughout the hardwood forests of eastern North America. regenerating oak *(Quercus)* stands on productive upland sites (oak SI_{50} > 60) is a formidable challenge for resource managers (Loftis and McGee 1993). The shelterwood system is often recommended to promote oak regeneration when lacking (Sander et al. 1983). However, in the Piedmont, this system usually fails because of intense competition from yellow-poplar *(Liriodendron tulipifera),* red maple *(Acer rubrum),* and sweetgum *(Liquidambar styraciflua)* developing in response to overstory removal and forest floor disturbance (O'Hara 1986, Kays et al. 1988).

Loftis (1990) proposed herbicide treatment to enhance oak regeneration before a shelterwood cut, but this method has not worked well in the Piedmont (Kass and Boyette 1998). Other drawbacks to this approach are its expense, $701 ac or more, and the time needed, 10 yr or more, before the cost is recovered by selling the timber (Loftis 1990). For many landowners, an expensive treatment carried for a decade or more before receiving financial benefits is unacceptable (Lorimer 1989).

Van Lear and Watt (1993) advocated preharvest prescribed burning to favor oak regeneration. This approach creates the same stand structure as preharvest herbicide application but has the drawback of requiring multiple burns over several years (Barnes and Van Lear 1998).

The cost, effort, and time involved in herbicides and preharvest burning have led, in part, to productive upland oak stands in the Piedmont either being high-graded and/or converted to loblolly pine *(Pinus taeda)* plantations (authors' personal observation). Given the abundance of mature oak stands on productive upland sites in the Piedmont region and high pine stumpage prices, high-grading and conversion to pine will probably increase in the future. Landowners and resource managers wanting to regenerate oak stands need an efficient means of doing so.

Three recent prescribed fire studies indicate that burning of shelterwood stands may solve this dilemma. The studies were conducted in fully stocked, mature, mixed-oak Stands (BA = 120 ft^2/ac, age = 100 yr) on productive upland sites (Typic Hapludult soils, oak SI_{50} ranged from 70 to 80) in the Piedmont of Virginia. While these studies are or will soon be available in other publications, they will be highlighted here to provide background for this paper.

In 1993, the Virginia Department of Game and Inland Fisheries (VDGIF) prescribe-burned two oak-dominated shelterwood stands that contained dense regeneration of red maple, sweetgum. and yellow-poplar (Keyser et al. 1996). It was found that summer burning reduced densities of these competitors by 82 to 96% while oak density decreased by only 11%.

Two years later, Brose and Van Lear (1998) expanded on VDGIF's pilot study by examining responses of hardwood regeneration to prescribed fires conducted in shelterwood stands during different seasons and at differ-

---

NOTE: P.H. Brose is the corresponding author. and he can be reached at Phone: (864) 656-4496; Fax: (864) 656-1407; E-mail: phbrose@clemson.edu. Manuscript received April 23.1997, accepted September 15, 1998.

Reprinted from the *Southern Journal of Applied Forestry,* Vol. 23, *No.* 3, August 1999. Not for further reproduction.

ent intensities. Results of VDGIF's pilot study that oak regeneration was more resistant to fire than its competitors were confirmed. In addition, fire intensity was found to be critical in controlling red maple and yellow-poplar (Table 1) and that sprouting oaks improved in form and growth rate, further strengthening their competitive ability. However, yellow-poplar and other competitors were still present following burning, implying that additional burning may be necessary to ensure eventual oak domination.

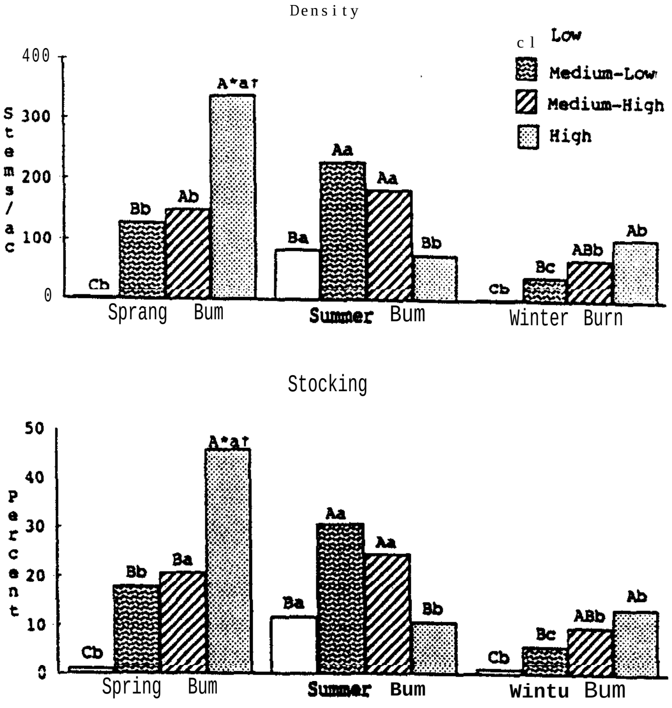
Brose et al. (1999) reexamined the density of oak and yellow-poplar regeneration in the 1995 burn treatments in light of their stocking and spatial patterns. It was found that adequate free-to-grow oak regeneration to ensure eventual oak-dominated areas where medium to high intensity fires occurred during the spring or summer (Figure 1).

All of these findings have led us to believe that shelterwood harvesting followed by prescribed fire is a reliable approach to regenerating oakstands on productive upland sites and should be applicable on similar sites throughout the Piedmont region. The objectives of this paper are to describe how to apply this shelterwood-bum technique and to discuss its benefits.

The Prescription

Appropriate Sites

At this time, this technique is recommended on fully stocked, mature, mixed-oak stands on upland sites in the Piedmont region. These are defined as having basal area of at least 100 ft^2/ac, age more than 80 yr. and an oak SI_{50} of 70 to 80. The technique has not yet been tested on upland stands outside these parameters nor on vastly different sites such as bottomlands or mountain coves where different competitors and environmental factors must be considered. With further research and modification, this technique may be applicable on a wide array of sites throughout the eastern states.



* Bars with different uppercase letters are different within that treatment (alpha = 0.05).

† Bars With different lowercase letters are different within that fire intensity level (alpha = 0.05).

Figure 1. Effect of increasing fire intensity within season-of-burn on density and stocking of free-to-grow oak regeneration in shelterwood stands in the Piedmont of central Virginia (Brose et al. 1999).

Pm-existing Conditions

Before applying this technique, twoconditions must exist. First, there must be existing, albeit suppressed, oak regeneration in the stand, a common situation (Lorimer 1993, Lorimer et al. 1994). If no oak regeneration is present, then delay applying the technique until 2 or 3 yr after a good acorn crop establishes oak seedlings. Existence of oak reproduction is critical to this technique because of the manner many oak seedlings become established initially.

Table 1. Percent mortality (mean ± 1 SE) of advance regeneration by season-of-bum and fire intensity in shelterwood stands in the Piedmont of central Virginia (Brose and Van tear 1998).

	Fire intensity*			
Species	Low	Medium-low	Medium-high	High
Winterbum				
Hickory	15 ± 7 C†a††	13 ± 9 Da	18 ± 9 Da	15 ± 4 Da
Oak	16 ± 7 Ca	14 ± 7 Da	17 ± 7 Da	20 ± 9 Da
Redmaple	13 ± 7 Cc	30 ± 9 CDb	34 ± 9 CDb	67 ± 4 Ba
Yellow-poplar	54 ± 8 Ab	78 ± 9 Aa	74 ± 11 Aa	76 ± 6 Aa
Spring burn				
Hickory	9 ± 5 Cb	19 ± 9 Db	14 ± 9 Db	37 ± 11 Ca
Oak	10 ± 9 Ca	16 ± 7 Da	16 ± 7 Da	26 ± 7 Ca
Redmaple	23 ± 8 BCc	34 ± 9 Cc	52 ± 9 Bb	74 ± 9 ABa
Yellow-poplar	68 ± 13 Ab	82 ± 9 Aa	90 ± 9 Aa	92 ± 9 Aa
Summer burn				
Hickory	10 ± 3 Cb	18 ± 5 Db	33 ± 9 Ca	47 ± 9 Ba
Oak	23 ± 3 Bb	44 ± 6 BCa	53 ± 7 Ba	55 ± 9 Ba
Redmaple	41 ± 8 Aa	52 ± 5 Ba	52 ± 6 Ba	69 ± 9 Ba
Yellow-poplar	70 ± 9 Ab	81 ± 5 Aa	80 ± 10 Aa	89 ± 9 Aa

* n = 10 to 15 for each season-of-burn × intensity combination.

† Means followed by different uppercase letters are different within that fire intensity column (alpha = 0.05).

†† Means followed by different lowercase letters are different within that species row (alpha = 0.05).

The 3 to 5 yr interval also permits oak's primary competitors to respond to the initial cut. Yellow-poplar regeneration becomes established primarily from seeds stored in the forest floor (Beck 1990). Their germination is epigeal, i.e., Cotyledons emerge above ground (Beck 1990). Sweetgum produces numerous sprouts from dormant root buds when the main stem is damaged or killed (Kormanik and Brown 1967). Red maple reproduces via new seedling establishment (epigeal germination) and basal sprouting of existing stems (Walters and Yawney 1990).

Regeneration of these competitors is more vulnerable to subsequent disturbance than is oak reproduction. The epigeal germination of red maple and yellow-poplar seeds places the root collar above or at the groundline, making the seedlings especially vulnerable to surface fires. New sweetgum root sprouts are susceptible to top-kill for a few years after forming because they have not yet established their own root systems independent of the parent root system (Kormanik and Brown 1967, Hooket al. 1970, Francis 1983). Red maple stump sprouts are prone to many stem-rot fungi (Walters and Yawney 1990). and while fire may not directly eliminate these sprouts, it reduces their areal extent, probably hastens onset of disease, and ultimately reduces the likelihood of these sprouts being a long-term competitor to oak in the Piedmont region.

The growth strategy of these three hardwoods is opposite that of oak, emphasizing stand development in lieu of root growth, (Beck 1990. Kormanik 1990, Walters and Yawney 1990). The inherently small rootstocks of their regeneration further compromise their survival and vigor when top-killed by surface fires. Also, the partial overstory shade slows their height growth (Beck 1990, Kormanik 1990, Walters and Yawney 1990), keeping their regeneration sufficiently small to be susceptible to fire.

Another benefit of the 3 to 5 yr wait is the development of a continuous fine fuel bed. Fully stocked oak stands produce about 2.0 tons/ac/yr of leaf litter (Loomis 1975) so a shelterwood stand probably produces about half that amount. Bare areas created on the forest floor during harvest will be blanketed by this leaf fall. These leaves decay slowly (Loomis 1974) and become curly upon drying (Lorimer 1985), creating a porous fuel bed that maintains high flammability for months. The interval also enables residual trees to recover from stress associated with harvesting so they are better prepared for the stress of the bum.

The Prescribed Fire

Prescribed fire disturbs the forest floor, top-killing all regeneration and forcing rootstocks to sprout (Figure 2). Over millennia, disturbances such as fire selected for species that develop deep large root systems, like oak, and against species that emphasized shoot growth, like yellow-poplar (Pyne 1982).

The best time to bum for maximum reduction of competitors is in the spring (Brose and Van Lear 1998). At this time, leaf expansion lowers root carbohydrate reserves, further accentuating growth strategy differences between oak and its competitors (Hodgkins 1958, Langdon 1981). Also, favorable weather (warm temperatures, low humidities, sunny days, and southerly winds) create numerous burning opportunities (Table 2). Disadvantages of spring burning include increased probability of fire escape and greater overstory tree damage/mortality (Table 3). These problems can be minimized with good planning and execution of bums.

Table 2. **Benefits** of **prescribed** burning in oak-dominated shelterwood stands in different seasons (Brose and Van Lear 1998, Brose and Van Lear 1999).

General (common to all seasons)
1. Improve stem fon of oak regeneration.
2. Accelerate height growth of oak reproduction for at least 2 yr.
3. Accelerate height growth of competitors for only I yr.

Spring
1. Numerous opportunities for burning at moderate to high fire intensities.
2. Minimal mortality to existing oak regeneration, regardless of fire intensity.
3. Good to excellent density reduction of less desirable hardwoods at moderate to high fire intensities.
4. Stimulate fruiting of soft mast shrubs.
5. Increase abundance and diversity of herbaceous plants.

Summer
1. Good to excellent density reduction of competing hardwoods at moderate to high fire intensities.
2. Little damage and mortality to residual crop trees.
3. Low risk of fire escape.

Fall and Winter
1. Minimal mortality to existing oak regeneration, regardless of fire intensity.
2. Fair to good density reduction of competing hardwoods.
3. Little damage and mortality to residual crop trees.
4. Stimulate fruiting of soft mast shrubs.

Summer fire produces results comparable to spring fire (Table 2) but presents fewer burning opportunities as steady winds of 5 to 10 mile/hr are needed to offset higher humidities and partial shade (Table 3). Fall and winter burning will not produce the competition control of growing-season fires (Tables 2 and 3) because of marginal burning conditions and full root carbohydrate reserves (Hodgkins 1958, Langdon 1981).

Table 3. Drawbacks of prescribed burning oak-dominated sheltemood stands in different seasons (Brose and Van Lear 1998, Brose and Van Lear 1999).

General (common to all seasons)
Smoke drift into sensitive areas.
I: Public misconceptions about fire.
3. Conflicts with other natural resource user groups.

Spring
1. Increased possibility of a fire escape.
2. Increased probability of damaging or killing residual crop trees.
3. Burning coincides with nesting season for wildlife.

Summer
1. Limited burning opportunities.
2. Significant oak mortality as fire intensity increases.
3. Natural decay cycle reduces amount of tine fuels.
4. Less stimulation of soft mast shrubs and herbaceous plants relative to spring burning.

Fail and Winter
1. Limited burning opportunities.
2. Less density reduction of competing hardwoods relative to spring and summer burning.
3. Less stimulation of herbaceous plants relative to spring burning.

Buckner, E. 1983. Archaeological and historical basis for forest succession in eastern North America. P. 182-187 *in* Proc. of 1982 Soc. Am. For. Nat. Conv. SAF Publ. 83-04.

Clatterbuck, W.K.. and J.S. Meadows. 1993. Regenerating oaks in the bottomlands. P. 184-196 in Oak regeneration: Serious problems, practical recommendations. Loftis, D., and C. McGee (eds.). USDA For. Serv. Gen. Tech. Rep. SE-GTR-84.

Francis, J.K. 1983. Suckering and root connections of sweetgum on clayey soils. P. 189-192 in Proc. of 2nd South. Silvic. Res. Conf., E. Jones (ed.). USDA For. Serv. Gen. Tech. Rep.SE-GTR-24.

Hanks L.F. 1976. Hardwood tree grades for factory lumber. USDA For. Serv. Res. Pap. NE-333. 7 p.

Hodgkins, E.J. 1958. Effect of tire on undergrowth vegetation in upland southern pine forests. Ecology 39:36-46.

Hook, D.D., P.P. Kormanik, and C.L. Brown. 1970. Early development of sweetgum root sprouts in coastal South Carolina. USDA For. Serv. Res. Pap. SE-RP-62.

Kass, D.J.. and W.G. Boyette. 1998. Preharvest herbicide method todevclop competitive oak reproduction in upland oak stands of the mountains and Piedmont of North Carolina-seven year results. P. 253-256 in Proc. of 9th South. Silvic. Res. Conf.. T. Waldrop (ed.). USDA For. Serv. Gen. Tech. Rep. SE-GTR-48.

Kays, J.S.. D.W. Smith, S.M. Zedaker, MD R.E. Kreh. 1988. Factors affecting natural regeneration of Piedmont hardwoods. South. J. Appl. For. 12 (2):98-101.

Keyser, P.D.. P.H. Brose, D.H. Van Lear, and K.M. Burtner. 1996. Enhancing oak regeneration with fire in shelterwood stands: Preliminary Trials. P. 215-219 in Trans. N. Am. Wildl. Natur. Resour. Conf.. Wadsworth. K.. and R. McCabe (eds.).

Kolb, T.E.. K.C. Steiner, LH. McCormick, and T.W. Bowersox. 1990. Growth response of northern red oak and yellow-poplar seedlings to light, soil moisture, and nutrients in relation to ecological strategy. For. Ecol. Manage. 38:65-78.

Kormanik, P.P. 1990. Sweetgum. P. 400-405 in Silvics of North America 2: Hardwoods. USDA For. Serv. Agric. Handb. 654.

Kormanik, P.P.. and C.L. Brown. 1967. Root buds and the development of root suckers in sweetgum. For. Sci. 13:338-345.

Korstian, C.F. 1927. Factors controlling germination and early survival of oaks. Yale School of Forestry Bull. 19. 115 p.

Langdon, O.G. 1981. Some effects of prescribed tire on undentory vegetation in loblolly pine stands. P. 143-153 *in* Prescribed fire and wildlife in southern forests. Wood. G.W. (cd.). Clemson University, Georgetown, SC.

Lloyd, F.T.. and T.A. Waldrop. 1993. Relative growth of oaks and pines in natural mixtures on intermediate and xeric Piedmont sites. P. 196-201 *in* Oak regeneration: Serious problems, practical recommendations, Loftis, D.. and C. McGee (eds.). USDA For. Serv. Gen. Tech. Rep. SECTR-84.

Loftis, D.L. 1983. Regenerating Southern Appalachian hardwoods with the shelterwood method. South. J. Appl. For. 7 (4):212-217.

Loftis, D.L. 1990. A shelterwood method for regenerating ted oak in the Southern Appalachians. For. Sci. 36:917-929.

Loftis, D.L.. and McGee. C.E. (eds.). 1993. Oak regeneration: Serious problems. practical recommendations, Symp. Proc. USDA For. Serv. Gen. Tech. Rep. SE-GTR-84.3 19 p.

Loomis. R.M. 1974. Some forest floor fuelbed characteristics of black oak stands in southeast Missouri. USDA For. Serv. Res. Note NC-RN-162. 4 p.

Loomis. R.M. 1975. Annual changes in forest floor weights under a southeast Missouri oak stand. USDA For. Serv. Res. Note NC-RN- 184.3 p.

Lorimer, C.G. 1985. The role of fire in the perpetuation of oak forests. P. 8-25 *in* Challenges of oak management and utilization, Johnson J. (ed.). Univ. Wisconsin Coop. Ext. Serv.

Lorimer, C.C. 1989. The oak regeneration problem: New evidences on causes and possiblesolutions. Univ. Wisconsin-Madison Natur. Resour. Bull. 8.3 I p.

Lorimer, C.G. 1993.Causesoftheoakregenentionproblem.P. 14-39 *in* Oak regeneration: Serious problems, practical recommendations. Loftis, D.. and C. McGee (eds.). USDA For. Serv. Cen. Tech. Rep. SE-CTR-84.

Lorimer, C.G.. J. W. Chapman. and W.D. Lambert. 1994. Tall understory vegetation as a factor in the poor development of oak seedlings beneath mature stands. Ecology 82:227-237.

Miller, G.W.. P.B. Wooo. and J.V. Nichols. 1995. Two-age silviculture: An innovative tool for enhancing species diversity and vertical structure in Appalachian hardwoods. P. 175-182 in Forest health through silviculture. Eskew, L.G. (comp.). USDA For. Serv. Gen. Tech. Rep. RM-GTR-67.

Miller, G.W.. and J.N. Kochenderfer. 1998. Maintaining species diversity in the central Appalachians. J. For. 96 (8):28-33.

Nix, L.E. 1989. Early release of bottomland oak enrichment plantingsappears promising in South Carolina. P. 379-383 in Proc. of 5th Bienn. South. Silvic. Res. Conf.. J. Miller (ed.). USDA For. Serv. Gen. Tech. Rep. SD. GTR-74.

O'Hara, K.L. 1986. Developmental patterns of oak and yellow-poplar regeneration after release in upland hardwood stands. South. J. Appl. For. IO (4):244-248.

Pyne, S. 1982. Fire in America. Princeton Press. 654 p.

Sander, I.L. *1971.* Height growth of new oak sprouts depends on size of advance regeneration. J. For. 67:809-81 l.

Sander, I.L., C.E. McGee, K.G. Day, and R.E. Willard. 1983. Oak-hickory. P. 116-120 *in* Silvicultural systems of the major forest types of the United States. Burns, R.M. (ed.). USDA For. Serv. Agric. Handb. 445.

Van Lear, D.H., and T.A. Waldrop. 1989. History, uses, and effects of fire in the Appalachians. USDA For. Serv. Gen. Tech. Rep. SE-54.20 p.

Van Lear, D.H.. and J.M. Watt. 1993. The role of tire in oak regeneration. P. 66-78 *in Oak* regeneration: *Serious* problems. practical recommendations, Loftis, D., and C. McGee (eds.). USDA For. Serv. Gen. Tech. Rep. SE-GTR-84.

Waldrop, T.A. 1997. Four site-preparation techniques for regenerating pine-hardwood mixtures in the Piedmont. South. J. Appl. For. 21 (3): 116-122.

Waldrop, T.A.. and F.T. Lloyd. 1991. Forty years of prescribed bunting on the Santee fire plots: Effects on overstory and midstory vegetation. P. 45-50 in Fire and the environment: Ecological and cultural perspectives. Nodvin, S.C.. and T.A. Waldrop (eds.). USDA For. Serv. Gen. Tech. Rep. SE-GTR-69.

Walters, R.S.. and H.W. Yawney. 1990. Red maple. P. 60-69 *in* Silvics of North America 2: Hardwoods. USDA For. Serv. Agric. Handb. 654.