UPLAND OAK REGENERATION AND MANAGEMENT

David L. Loftis[1]

Abstract—In oak-dominated plant communities and in other communities where oaks are important, the keys to natural regeneration of upland oak components are (1) to ensure presence of competitive regeneration sources, and (2) to provide timely, sufficient release of these sources. Regeneration sources vary significantly among different types of plant communities and disturbance regimes. Options for timely, sufficient release of oak regeneration sources include stand structures associated with even-aged, two-aged, and uneven-aged silvicultural systems. I discuss the nature and management implications of these variations, the regeneration options, and stress the importance of evaluating oak regeneration potential.

INTRODUCTION

The remarkable book by Johnson, Shifley, and Rogers (Johnson and others 2002) covers much of what I am going to say either directly or indirectly, and in greater depth. However, I will provide a few additional insights based on my work in oak silviculture over the last 30 years.

Upland oaks have two fundamental requirements for successful regeneration and subsequent management, both in oak-dominated systems and in systems where oaks are important components of mixed hardwood forests. These two requirements are:

1. the presence of competitive sources of oak regeneration
2. timely, sufficient release of these oak regeneration sources.

The first requirement—competitive oak regeneration sources—is a restatement of the First Law of Oak Silviculture; i.e., successful oak regeneration after harvest will come from advance reproduction that exists in the current stand and stump sprouts from trees that are harvested from the current stand. I will discuss progress that has been made in assessing (1) the competitiveness of oak regeneration sources and (2) silvicultural practices to develop competitive oak regeneration sources.

The second requirement—timely, sufficient release—concerns the timing and pattern of tree removal from the existing stand to ensure the regeneration sources develop, ultimately, into overstory trees. I will discuss a broader range of silvicultural systems that can provide timely, sufficient release than we envisioned 30 years ago.

COMPETITIVE REGENERATION SOURCES

Assessing Regeneration Potential

When I began research in oak regeneration, the notion was well accepted that advance reproduction and stump sprouts were the sources of successful regeneration after harvest cutting. This First Law of Oak Silviculture was based on early work done by Leffleman and Hawley (1925), Korstian (1927), Liming and Johnson (1944), and on work in the 1950s, 1960s, and 1970s (Clark and Watt 1971, Sander 1971, Sander and Clark 1971).

The next logical step was important—the development of methods and models to predict the oak component of the next stand, based on the population of regeneration sources in the current stand. The foundation of the models was the relationship between the size of advance reproduction and postharvest development (Sander 1971), and the relationship between tree size and age, and stump-sprout development (Johnson 1977). Researchers developed models for the Ozarks (Dey 1991, Sander and others 1984) and for the Southern Appalachian (Loftis 1990a). The models were applied to sample data collected from stands considered for harvest. For example, I developed a simple model that predicted the probability of success of advanced red oak reproduction 20 years after harvest (dominance probability) based on the size of advance reproduction and oak site index (Loftis 1990a). I also adapted dominance probabilities for stump sprouts from Paul Johnson's work (Johnson 1977). Therefore, knowing the site index and the size distribution of red oak regeneration sources, a silviculturist could predict what the oak component would be in the next stand. This development of prediction models was an important step forward. Previously, when we cut stands, we were either satisfied with the outcome, or we lamented that the oak component in the new stand was much less than we desired or much less than was in the previous stand. With the development of these models we had tools to give us information on regeneration outcomes before we made the cut, and an opportunity to apply different management techniques to achieve a different outcome.

Even before I completed development of this model, I was uneasy. It considered competition only implicitly as a function of site index. That is, my interpretation of the inverse relationship between site index and dominance probability was that competition increases as site quality increases. For a stem of a given size, it is reasonable to expect that it would have a better chance to become dominant or codominant on site index 70 than on site index 90. What bothered me was the assumption of an "average competitive environment" when the competitive environment within even a single stand can vary widely. In reality, it makes a huge difference whether a 1-inch basal diameter advance red oak stem is going to be competing against a yellow-poplar stump-sprout or against other small advance reproduction.

[1] Project Leader, USDA Forest Service, Southern Research Station, Asheville, NC 28806.

Citation for proceedings: Spetich, Martin A., ed. 2004. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. SRS–73. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 311 p.

Another thing bothered me. On higher quality sites where I observed oaks competing successfully after crown closure (stem exclusion stage), there was an absence of yellow-poplar. Apparently, at least on a patch-wise basis, abundant, well-developed advance reproduction of oaks (and other species) competitively excluded yellow-poplar of seedling origin. Height-age (site index) curves for yellow-poplar and oak (Beck 1962, Doolittle 1958, Olson 1959) indicate that even when oak is free to grow at crown closure, if surrounded by free-to-grow yellow-poplar, oak is going to lose the battle. Only where yellow-poplar is excluded prior to crown closure will oaks be successful. The patchy nature of early regeneration development might not be apparent in older stands, since a patch might ultimately contribute only one or two dominant or codominant oak trees, and, by age 60, these big oaks would appear intimately mixed with other species.

Since the 1980s I have been trying to flesh out an intuitive, conceptual model that addresses these phenomena, a model in which competition among regeneration sources is the main driver (Loftis 1989). The prediction system builds on the concepts of Egler (1954) and Noble and Slatyer (1980), as well as the applied work of Johnson (1980) and Marquis (1984). The predictions of postharvest species composition at the time of crown closure are driven by data collected from small plots, say 0.01 acre, in the mature stand in which all existing regeneration sources are enumerated by size class. The model will stochastically add new seedlings of some species, e.g. yellow-poplar to plots when appropriate, and it will stochastically add stump sprouts from trees present on the plot. The model chooses several "winners" on each plot from the existing reproduction sources and from added seedlings on that plot, based on a ranking of expected postharvest performance. The model then combines the winners from each plot into a summary of stand-level species composition; including, but not restricted to oaks. This modeling approach provides the capability to deal with altered competition situations resulting from silvicultural practices. These practices might include the elimination of stump sprouts with herbicides or an altered size class distribution of regeneration sources resulting from silvicultural treatments designed to enhance advance reproduction development. I have developed a computer prototype of this model and an enhanced version should be available in 2004.

In the last two decades researchers have developed useful evaluation tools and prediction models. I hope managers will use these models in the silvicultural prescription process in the future. Assessing regeneration potential is the critical first step in regenerating oaks.

Enhancing Regeneration Potential for Oaks

If these models predict an unsatisfactory oak component in the next stand, we must do one of the following:

1. make the oaks more competitive
2. reduce competition from other species
3. do a combination of the two.

Either directly or indirectly, successful silvicultural treatments are going to cause one of these outcomes. This simple construct provides a useful context for discussing silvicultural treatments designed to favor oaks.

In a given stand, there is not a lot we can do to alter the population of oaks that will produce stump sprouts. To make oaks more competitive, we must increase the number and size of advance reproduction, enhancing their ability to sustain more rapid height growth after release. For oak-dominated ecosystems on more xeric sites, oak advance reproduction that can compete successfully after disturbance accumulates over time in mature stands. However, on more mesic sites oak advance reproduction that can compete after disturbance does not accumulate in mature stands (Johnson and others 2002, Loftis 1983a). Rather, it cycles in and out of the system with new seedling establishment after good acorn crops followed by mortality. But the survivors at any point do not develop into advance reproduction of a size that would be competitive if released by overstory removal (Loftis 1983a, McGee 1967). Interrupting this cycle of establishment and mortality to enhance survival and growth of advance oak reproduction requires a silvicultural treatment that alters stand structure and the light environment. By removing midcanopy and some lower canopy trees with herbicides, leaving a main canopy with no large gaps, we have increased survival and growth of small oak advance reproduction in the Southern Appalachians (Loftis 1990b). This treatment allows the population of small oak advance reproduction to develop after a few years into a population of larger advance reproduction, making oaks more competitive after release. This process also reduces competition from other species. Potential sprouts from midcanopy and lower canopy trees are treated with herbicides, thereby directly reducing competition from these trees both before and after overwood removal. The reduction in competition from yellow-poplar is more subtle. First, while the residual canopy with no canopy gaps is sufficient to allow oak seedlings to develop, it is not sufficient to allow the establishment and development of yellow-poplar. Secondly, new yellow-poplar seedlings that become established after overwood removal will be in an inferior competitive position, at least on a patch-wise basis, because of the development of large advance reproduction of oaks and other species.

Prescribed burning is another silvicultural treatment that has received a great deal of attention over the past 20 years. A number of hypothetical mechanisms might favor oak reproduction:

1. burning could alter stand structure and the light environment, providing for the development of larger advance reproduction—making oaks more competitive
2. burning could top-kill poorly formed oak advance reproduction, transforming them from stems that would respond slowly to release into thrifty sprouts that respond quickly to release—making oaks more competitive
3. burning, particularly recurrent burning, could kill or inhibit the development of competing vegetation—reducing competition from other species

4. burning could alter the seedbed, resulting in increased establishment of more oak seedlings—making oaks more competitive
5. burning could adversely affect insect predators of acorns, resulting in more oak seedlings—making oaks more competitive.

Understanding the role of fire in oak ecosystems and devising useful prescriptions to effect desired oak regeneration outcomes requires that these and other hypotheses be tested. Several ongoing studies are testing these hypotheses in various places and in different kinds of oak ecosystems. For example, after a single fire on relatively mesic sites in the Southern Appalachians, I found that survival of northern red oak seedlings was reduced on burned plots, and that, over time, surviving oak seedlings grew no better or worse than seedlings on nonburned plots (Loftis 1990b). Burning had no apparent effect on stand structure and the light environment. On somewhat less mesic sites, prescribed burning reduced the number and vigor of yellow-poplar competitors after burning in stands where a shelterwood cut had been conducted several years before (Brose and Van Lear 1998). Several other studies are ongoing (Dey and Hartman, in press; Iverson and others, in press) and viable prescriptions for prescribed burning may emerge from some of these studies. Workable prescriptions may differ from one upland oak ecosystem to another, and there may be some ecosystems where prescribed fire may play no role at all.

Another area of silvicultural practice is planting. Researchers have expended a good deal of effort developing technology to produce oak seedlings that can perform satisfactorily after outplanting (Johnson 1988, 1989; Kormanik and others 1998) making oaks more competitive. Some have suggested that the best opportunities for planting oaks successfully are on sites of intermediate quality, in a site index range from 60 to 75 feet (Johnson and others 2002) where competition is less severe. Attempts to plant oaks on higher quality sites have certainly met with limited success (Loftis 1979, McGee and Loftis 1986). Planting in clearcuts on mesic sites in the Southern Appalachians where site index exceeds 80 feet requires herbicides to reduce competition of other species, yellow-poplar in particular (Personal communication. 2000. Paul Kormanik, Silviculturist, USDA Forest Service, Southern Research Station, Forestry Sciences Laboratory, Athens, GA 30602-2044).

Another approach to planting oaks is planting under a shelterwood (Johnson and others 1986; Weigel and Johnson 1998a, 1998b). This approach is somewhat analogous to the shelterwood method described above for natural regeneration. However, in this case, the advance reproduction is planted in conjunction with a shelterwood and given a few years to become well established and to expand root systems before a partial or final removal cut opens the stand and the associated competition develops, making the oaks more competitive. Treating understory and midcanopy trees during the period under the shelterwood both increases light for the planted oaks and reduces competition from other species after overwood removal (Johnson and others 2002).

In my opinion, devising and implementing silvicultural strategies to favor oaks should usually involve treatments that both make oaks more competitive and that reduce competition from other species. The modeling approach I outlined is designed, at least conceptually, to provide insights into how well treatments accomplish these objectives on a stand-specific basis.

Intermediate stand treatments can also be used to directly favor oak and typically do so by reducing competition from other species in such operations as cleanings and thinning (Shifley, in press).

TIMELY, SUFFICIENT RELEASE OF OAK REGENERATION SOURCES

A generation ago the prevailing opinion was that even-aged silviculture was the preferred approach to managing oak: “Oak grows best in full sunlight, and oak silviculture should be even-aged.” (Clark and Watt 1971: p. 38).

In the ensuing 30 years, we have found a number of ways to provide timely, sufficient release of oak regeneration sources that result in silviculture classified as other than even-aged.

Where competitive oak regeneration sources are present, either as a result of intrinsic processes or as a result of prior disturbances, clearcutting or overstory removal will result in successful oak regeneration (Beck 1988, Johnson and others 2002, Roach and Gingrich 1968). Successful oak regeneration has also been achieved by applying a two-cut shelterwood when competitive advance reproduction was present at the initial cut (Loftis 1983b). In this case, residual basal areas after the initial cut included plots with 33 and 66 square feet, and the level of overwood retention did not result in any differential species response. Yellow-poplar and other less shade-tolerant species developed about as they would have in a clearcut, although with some reduction in height growth. Normally, a final removal cut would be made no more than 10 to 20 years after the initial cut to ensure continued development of the oak regeneration.

The shelterwood method I designed to take advantage of differential species response between northern red oak and yellow-poplar may not work everywhere (Shuler and Miller 1995) or may need to be modified for different ecosystems. And in some ecosystems, an aggressive, shade-tolerant species, e.g. sugar maple, might be better able to take advantage of the modest increase in the light resource than oak.

Even-aged silviculture has been successful for oak regeneration. As noted earlier, when competitive regeneration sources are present as a result of intrinsic processes, disturbance, or treatment, a shelterwood will result in successful oak regeneration. Therefore, it is reasonable to believe that a lower residual basal area shelterwood—a shelterwood with reserves—designed to create a two-aged stand would also successfully regenerate oak. Oak did regenerate well on one lower quality site where we reduced basal area to about 20 square feet per acre, where stump-sprout potential was high, and large advance reproduction was present at the time of the cut. In another stand on a high-quality site where we had reduced midcanopy and lower canopy trees to favor the development of large oak advance reproduction, successful oak regeneration is occurring at crown closure 5 years after creating a shelterwood with reserves. The patches at this site are large enough to ensure that oak will be a component of the next new stand. These methods create stands that "may be two-aged or tend towards an uneven-aged condition as a consequence of both an extended period of regeneration and the retention of reserve trees that may represent one or more ages classes" (Helms 1998: p. 151). Two-aged methods provide more complex stand structures to satisfy nontimber objectives.

Uneven-aged silviculture applied to oak stands offers intriguing possibilities and uncertainties. Managers may have some concerns over whether to apply group selection as an extension of the structural control methodology developed for single-tree selection, or as small-scale area control. However, in terms of biological response, oaks can be successfully regenerated if competitive regeneration sources are present when the openings are created. In the Southern Appalachians, in group-selection openings of one-fifth acre or larger, the same species composition develops as in much larger clearcut openings (Beck 1988). Yellow-poplar, one of our more shade-intolerant species, regenerated quite well in these small openings 25 years after they were created. An intriguing possibility is related to a common response observed along edges of group-selection openings and extending into the surrounding stand. The increase in light penetrating into the surrounding stand usually results in development of oak advance reproduction if small oak seedlings are present when openings are created, providing an opportunity to favor oaks in regeneration with a subsequent enlargement of the opening. In addition, group selection should provide, at least theoretically, the flexibility necessary to take advantage of the sometimes patchy distribution of competitive, large advance reproduction in forest stands.

Regenerating oaks using single-tree selection has generally been viewed negatively. In a Southern Appalachian study of single-tree selection on relatively mesic sites (Della-Bianca and Beck 1985), oak regeneration and regeneration of other overstory species generally has been far from sufficient. Since 1946, managers have applied structural control using a reverse-J distribution with residual basal area target of 65 square feet, a maximum diameter of 34 inches and a q of 1.4 (2-inch classes). After more than 50 years and four cutting cycles, we have a stand that roughly approximates a reverse-j (negative exponential) distribution, but most of the smaller diameter trees are noncanopy, shade-tolerant species. In the study, the recent addition of the application of herbicides has produced some encouraging trends with respect to development of large oak advance reproduction. However, how or if we can provide timely, sufficient release of this advance reproduction using single-tree selection remains to be seen.

On the other hand, there is at least one documented success using single-tree selection in the relatively more xeric western range of oaks (Lowenstein 1996). It seems reasonable to wonder whether or not some form of single-tree selection might also work on xeric sites in other parts of the oak range where advance reproduction capable of competing after release tends to be abundant.

CONCLUSIONS

There are a number of conclusions about regeneration and management for which we can find general consensus:

- The First Law of Oak Silviculture has not been repealed. We have to have competitive oak regeneration sources present when we begin removing the stand
- These competitive oak regeneration sources can result from natural stand processes including natural disturbances, or
- We can implement silvicultural treatments to develop competitive regeneration sources.
- These silvicultural treatments can (1) make oaks more competitive, (2) reduce competition from other species, or (3) both of the above
- Management of oak stands can potentially be even-aged, two-aged, or uneven-aged
- We still have a lot to learn

LITERATURE CITED

Beck, D.E. 1962. Yellow-poplar site index curves. Res. Note SE-16. Asheville, NC: U,S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. [Number of pages unknown].

Beck, D.E. 1988. Clearcutting and other regeneration options for upland hardwoods. In: Proceedings of the sixteenth annual hardwood symposium of the Hardwood Research Council. Cashiers, NC: [Publisher unknown]: 44-54.

Brose, P.H.; Van Lear, D.H. 1998. Responses of hardwood advance regeneration to seasonal prescribed fires in oak-dominated shelterwood stands. Canadian Journal of Forest Research. 28: 331-339.

Clark, F.B.; Watt, R.F. 1971. Silvicultural methods for regenerating oaks. In: Proceedings of the oak symposium. Upper Darby, PA: U.S. Department of Agriculture, Forest Service: 34-43.

Della-Bianca, L.; Beck, D.E. 1985. Selection management in Southern Appalachian hardwoods. Southern Journal of Applied Forestry. 9: 191-196.

Dey, D.C. 1991. A comprehensive Ozark regenerator. Columbia, MO: University of Missouri. [Number of pages unknown]. Ph.D. dissertation.

Dey, D.C.; Hartman, G. [In press]. Effects of different large-scale prescribed burning regimes on advance reproduction in the Missouri Ozarks. In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Doolittle, W.T. 1958. Site index comparisons for several forest species in the Southern Appalachians. In: Proceedings of Soil Science Society of America. 22(5): 455-458.

Egler, F.E. 1954. Vegetation science concepts I. Initial floristic composition: a factor in old-field vegetation management. Vegetatio. 4: 412-417.

Helms, J.A., ed. 1998. The dictionary of forestry. [Place of publication unknown]: Society of American Foresters. 210 p.

Iverson, L.R.; Prasad, A.M.; Hutchinson, T.F. [and others]. [In press]. Fire and thinning in an Ohio oak forest: grid-based analyses of fire behavior, environmental conditions, and tree regeneration across a topographic moisture gradient. In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Johnson, P.S. 1977. Predicting oak stump sprouting and sprout development in the Missouri Ozarks. Res. Pap. NC-149. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. [Number of pages unknown].

Johnson, P.S. 1988. Undercutting alters root morphology and improves field performance of northern red oak. In: Proceedings of the 10th North American For. Biol. Workshop: 316-323.

Johnson, P.S. 1989. Growing hardwood nursery stock for planting on forest sites with special reference to northern red oak. In: Proceedings 1989 Northeastern area nurseryman's conference. [Place of publication unknown]: [Publisher unknown]: 46-62.

Johnson, P.S.; Dale, C.D.; Davidson, K.R.; Law, J.R. 1986. Planting northern red oak in the Missouri Ozarks: a prescription. Northern Journal of Applied Forestry. 3: 66-68.

Johnson, P.S.; Shifley, S.R.; Rogers, R. 2002. The ecology and silviculture of oaks. CABI Publishing. 503 p.

Johnson, R.L. 1980. New ideas about regeneration of hardwoods. In: Proceedings of the hardwood regeneration symposium. Forest Park, GA: Southeastern Lumber Manufacturing Association: 17-19.

Kormanik, P.P.; Sung, S.S.; Kass, D.J.; Schlarbaum, S.E. 1998. Effect of seedling size and first-order lateral roots on early development of northern red oak on mesic sites. Gen. Tech. Rep. SRS-20. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 247-252.

Korstian, C.F. 1927. Factors controlling germination and early survival in oaks. Yale University Sch. For. Bull. 19. [Place of publication unknown]: [Publisher unknown]. [Number of pages unknown].

Leffelman, L.J.; Hawley, R.C. 1925. The treatment of advance growth arising as a result of thinnings and shelterwood cuttings. Yale University Sch. For. Bull. 15. [Place of publication unknown]: [Publisher unknown]. [Number of pages unknown].

Liming, F.G.; Johnson, J.P. 1944. Reproduction in oak-hickory forest stands of the Missouri Ozarks. Journal of Forestry. 42: 175-180.

Loftis, D.L. 1979. Northern red oak performs poorly in North Carolina planting. Res. Note SE-277. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. [Number of pages unknown].

Loftis, D.L. 1983a. Regenerating red oak on productive sites in the Southern Appalachians: a research approach. Gen. Tech. Rep. SE-24. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 144-150.

Loftis, D.L. 1983b. Regenerating Southern Appalachian mixed hardwood stands with the shelterwood method. Southern Journal of Applied Forestry. 7: 212-217.

Loftis, D.L. 1989. Species composition of regeneration after clear-cutting Southern Appalachian hardwoods. In: Miller, James H., comp. Proceedings of the fifth biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 253-257.

Loftis, D.L. 1990a. Predicting post-harvest performance of advance red oak reproduction in the Southern Appalachians. Forest Science. 36: 908-916.

Loftis, D.L. 1990b. A shelterwood method for regenerating red oak in the Southern Appalachians. Forest Science. 36: 917-929.

Loewenstein, E.F. 1996. An analysis of the size- and age-structure of a managed uneven-aged oak forest. Columbia, MO: University of Missouri. [Number of pages unknown]. Ph.D. dissertation.

Marquis, D.; Ernst, R.L.; Stout, S.L. 1984. Prescribing silvicultural treatments in hardwood stands of the Alleghenies. Gen. Tech. Rep. N-96. [Place of publication unknown]: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

McGee, C.E. 1967. Regeneration in Southern Appalachian oak stands. Res. Note SE-72. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 6 p.

McGee, C.E.; Loftis, D.L. 1986. Planted oaks perform poorly in North Carolina and Tennessee. Northern Journal of Applied Forestry. 3: 114-116.

Noble, I.R.; Slatyer, R.O. 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. Vegetatio. 43: 5-21.

Olson, D.F., Jr. 1959. Site index curves for upland oak in the Southeast. Res. Note 125. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. [Number of pages unknown].

Roach, B.A.; Gingrich, S.F. 1968. Even-aged silviculture for upland central hardwoods. Agric. Handb. 355. [Place of publication unknown]: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Sander, I.L. 1971. Height growth of new oak sprouts depends on size of advance reproduction. Journal of Forestry. 69: 809-811.

Sander, I.L.; Clark, F.B. 1971. Reproduction of upland hardwood forests in the Central States. Agric. Handb. 405. [Place of publication unknown]: U.S. Department of Agriculture, Forest Service. [Number of pages unknown].

Sander, I.L.; Johnson, P.S.; Rogers, R. 1984. Evaluating oak advance reproduction in the Missouri Ozarks. Res. Pap. NC-251. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. [Number of pages unknown].

Schuler, T.M.; Miller, G.W. 1995. Shelterwood treatments fail to establish oak reproduction on mesic forest sites in West Virginia—10-year results. Gen. Tech. Rep. NE-197. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station: 375-387.

Shifley, S.R. [In press]. Oak growth and response to thinning. In: Spetich, M.A., ed. Upland oak ecology symposium: history, current conditions, and sustainability. Gen. Tech. Rep. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station.

Weigel, D.R.; Johnson, P.S. 1998a. Planting northern red oak in the Ozark Highlands: a shelterwood prescription. Tech. Brief TB-NC-6. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. [Number of pages unknown].

Weigel, D.R.; Johnson, P.S. 1998b. Planting white oak in the Ozark Highlands: a shelterwood prescription. Tech. Brief TB-NC-5. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. [Number of pages unknown].