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A Shelterwood Method for Regenerating Red Oak in the Southern Appalachians

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ABSTRACT. A shelterwood method is described that provides stand conditions that enhance the growth of established red oak advance reproduction, thereby improving the chances of maintaining an oak component in the next stand. Stocking of a mature, fully stocked stand is reduced to 60%, 65%, and 70% of initial stand basal area where oak site index is 70, 80, and 90 ft, respectively. The basal area reduction is accomplished from below using herbicides, leaving the main canopy essentially intact. This level and method of treatment prevents yellow-poplar, a primary competitor of red oak, from becoming established and growing prior to the final removal cut, and it eliminates most sprout competition from shade-tolerant subcanopy species after the final removal cut. The final removal cut can be made approximately 10 years after the initial treatment. FOR. SCI. 36(4):917–929.
ADDITIONAL KEY WORDS. Regeneration, prescribed fire.

NORTHERN RED OAK (*Quercus rubra* L.) is one of the most important tree species in Southern Appalachian forests. Its high quality wood and relatively rapid diameter growth make it among the most desirable sawtimber species there. In addition, its good, though somewhat infrequent, acorn crops are an important source of food for many wildlife species. The forest stands in which it occurs are esthetically appealing. Regenerating red oak, however, has proven difficult. Clearcutting and shelterwood cutting have given inconsistent results, and red oak is among the many Southern Appalachian species that have not responded well to single-tree selection. The objective of the research reported here was to determine how to manipulate mature stands to enhance the development of red oak advance reproduction, thereby improving its competitive ability in subsequent harvest cuts.

PREVIOUS EXPERIENCE

The importance of pre-existing vegetative structures (i.e., stump sprouts and advance reproduction) to the regeneration of the upland oaks has been well established (Carvell and Tryon 1961, Loftis 1983a, Loftis 1983b, Sander 1972, Sander 1971, Sander and Clark 1971). For oak stems greater than 2 in. dbh (those which would contribute stump sprouts to the next stand), the probability that sprouts will become dominants or codominants after a harvest cut is highest between 2 to 5 in. dbh and decreases with increasing stem diameter. For advance reproduction (stems with a basal diameter at groundline less than 2.0 in.), the

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probability that stems will become dominants or codominants increases with increasing basal diameter. Methods for predicting the contribution of these sources of regeneration to new stands are now available (Loftis 1988, Sander et al. 1984).

Advance reproduction is perhaps a more important source of regeneration for red oak in the Southern Appalachians than for other upland oaks. Other upland oaks typically occur on somewhat poorer quality sites, where mature stands contain a relatively large number of smaller diameter oak stems that sprout vigorously from stumps after a harvest cut (Schnur 1937). In mature stands on high-quality sites, however, red oak usually occurs as scattered, large individuals that have a low probability of providing dominant and codominant sprouts after harvest cutting. Sapling and pole-size red oak are few in number or absent (Loftis 1983a). On good sites, therefore, advance red oak reproduction is the primary source of regeneration. After a good acorn crop, seedlings usually become established in undisturbed stands, but mortality is high. After 10 years, survival may be as low as 10%. More importantly, surviving seedlings are still quite small—too small to compete well after overstory removal (Loftis 1983a). Manipulating mature stands to enhance the survival and growth of red oak advance reproduction prior to overstory removal is the essence of a shelterwood method to regenerate red oak.

In previous shelterwood studies in the Southern Appalachians, residual basal areas have ranged from 25 to 66 ft^2/ac, and the overwood has been retained from 5 to 13 years. Well-stocked stands have resulted, but species composition was essentially the same as in clearcuts with intolerant species, especially yellow-poplar (*Liriodendron tulipifera* L.), dominating. Oaks, including red oak, did not benefit from either higher residual basal area or longer periods of overstory retention. In these shelterwood cuts, the tolerant subcanopy was cut in addition to the overstory manipulation. Stand disturbance was sufficient to allow yellow-poplar to become established and grow, particularly in the canopy gaps. Although oak advance reproduction also grew, it was overtopped by yellow-poplar and sprouts from the tolerant subcanopy stems (Loftis 1983b).

Results of these studies suggest that a shelterwood method to regenerate oaks must provide for the development of large oak advance reproduction without allowing associated species to gain an advantage over the oaks. Overwood basal area must be high enough to prevent yellow-poplar from becoming established and growing, and the tolerant subcanopy must be sufficiently controlled to prevent it from dominating the regeneration.

In a shelterwood study in the Southern Appalachians, reducing stand basal area did not increase per acre production of acorns, nor did it improve conditions for oak seedling establishment (Beck 1977, McGee 1975). Korstian (1927) observed that undisturbed conditions may be optimum for oak seedling establishment. These results suggest that the preparatory and seed cuts of the classical shelterwood will not be part of the shelterwood sequence to regenerate oaks. Rather, the cuttings applied in a shelterwood to regenerate red oak should be considered removal cuts to exploit the presence of small advance oak reproduction—enhancing the development of and, finally, releasing advance reproduction that is already established.

There is some evidence that current oak stands may be the result of fire history, and, consequently, that prescribed fire might be a useful silvicultural practice in oak regeneration. Curtis (1959) found that the exclusion of fire in the prairie-forest transition area of Wisconsin resulted in a reversion of prairie to oak forest. Brown (1960) concluded that the prevalence of oak on his study plots in Rhode Island was the result of a long history of disturbance and burning. Little (1974) observed that in the absence of fire in southern New England, species composition is shifting from oaks to northern hardwoods on high quality sites.

The adaptability of the oaks to fire is related to their capacity to sprout from the root-cellar after top-kill (Liming and Johnson 1944). Seedlings of other species are more susceptible to root-kill by fire, thus giving oaks an ecological advantage over their associates (Niering et al. 1970, Swan 1970). A single fire, however, may not affect species composition in the understory, or may provide conditions more favorable for light-seeded species and those which store seeds in the forest floor. Therefore, recurrent fires may be the key to oaks predominating over their associates (Little 1974).

METHODS

Two studies were installed to examine the effects of stand manipulation on growth and survival of red oak advance reproduction. The first was installed on the Bent Creek Experimental Forest near Asheville, NC, in 1977. The second was installed in 1980 on the Chattahoochee National Forest near Blairsville, GA.

Bent Creek Study

Sixteen sites were chosen on the Bent Creek watershed in the summer of 1976. These sites were well stocked with mature mixed deciduous hardwoods that showed no evidence of disturbance over the last several decades. Species composition ranged from mixed oaks on the lowest quality sites (oak SI = 80 ft) to domination by yellow-poplar on the higher quality sites (oak SI = 96 ft). Red oak was a stand component on all sites.

In fall 1976, acorns were collected from 12 red oak trees on the experimental forest. Acorns were floated in water to remove culls and heat-treated in a water bath to kill weevils (*Curcullio* spp.) in otherwise sound acorns. After air-drying, acorns from the 12 trees were thoroughly mixed, placed in plastic bags, and stored at 38°F over winter. On each of the 16 sites a 140 ft × 140 ft treatment area (0.45 ac) was laid out, and a 40 ft × 40 ft plot was established in the center of the treatment area. In April 1977, acorns were removed from stratification and direct-seeded in the 40 ft × 40 ft plot in a 10 × 10 grid at 4 ft × 4 ft spacing. Three acorns were sown at each of the 100 seedspots and protected with cylindrical cages constructed with hardware cloth. Direct seeding in this study was intended to simulate a good seedling catch of natural seedlings which normally follows a bumper acorn crop.

One of four treatments was randomly assigned to each of the 16 plots: (1) canopy untreated and subcanopy untreated, (2) canopy untreated and subcanopy treated, (3) canopy treated and subcanopy untreated, and (4) canopy treated and subcanopy treated. The study design is, therefore, a factorial in a completely randomized design with two levels of each of two treatments, with four repetitions of each factorial combination. For statistical analyses a fixed-effects model was assumed. The canopy treatment consisted of removing, from below, 20% of the basal area contained in trees classified as being in the main canopy. The subcanopy treatment consisted of the elimination, with herbicides, of all stems 0.6 in. dbh or larger which were not in the main canopy. Tordon 101 [Picloram (4-amino-3,5,6-trichloropicolinic acid) + 2,4-dichlorophenoxyacetic acid] was applied with a tree injector to accomplish this treatment. Treatments were applied in August 1977.

Red oak seedlings surviving at the end of the 1977 growing season were permanently tagged and became the basis for measuring treatment effects. Seedspots which contained more than one seedling were thinned to one seedling per seedspot.

Georgia Study

In fall 1980, 30 0.25-ac circular plots were established in the Ivy Log Mountain section of the Brasstown District of the Chatahoochee National Forest north of Blairsville, GA. The criteria for plot selection was the presence of natural advance reproduction of red oak in mature stands of Appalachian hardwoods, no evidence of recent human disturbance, full stocking, and a site index of at least 65 ft at 50 years for oak. All stems greater than 0.6 in. dbh were tallied on each plot. All red oak advance reproduction within 30 ft of the plot center was permanently tagged and mapped by azimuth and distance from the plot center, and basal diameter and height of each stem was recorded. Ten permanent 0.001-ac subplots were established systematically to monitor the development of other woody vegetation.

A factorial combination of treatments was randomly assigned to the 30 plots in a completely randomized design, and a fixed-effects model was assumed for statistical analyses. Treatments consisted of two levels of prescribed burning (burn and no-burn) and five levels of basal area reduction (0, 10, 20, 30, and 40% of initial basal area), giving three repetitions of each factorial combination. Percent basal area reduction, rather than absolute basal area, was used to control treatment level because variation in species composition among mixed Southern Appalachian hardwood stands growing on sites of equal quality can result in quite variable absolute basal areas among apparently fully stocked stands.

Basal area was reduced by applying Tordon 101R as a cut surface treatment in the fall of 1980. Based on the 100% inventory of each plot, all trees in successively larger diameter classes (starting at 0.6 in. dbh) were injected until the assigned basal area reduction for a plot was reached. The burning treatment was applied in April 1981. Backing fires were prescribed because the longer residence time of backing fires should result in greater top-kill of vegetation.

RESULTS

Bent Creek Study

Three of the 16 plots had very low germination and first-year survival, caused primarily by rodent depredation. Exclusion of these plots from the study resulted in an unbalanced experiment. Tests of statistical significance of differences among treatment means ($P = 0.05$) used type III partial sums of squares from the General Linear Models procedure (SAS 1985).

Nine years after application, treatments had significantly increased both basal diameter (at groundline) and survival of red oak seedlings. Analysis of main effects indicates that both overstory and understory treatment increased basal diameter, while only overstory treatment had significantly affected survival. Means of the treatment combinations ranged from 0.14 in. basal diameter and 22% survival for the canopy untreated-subcanopy untreated combination to 0.36 in. basal diameter and 50% survival for the canopy treated-subcanopy treated combination (Table 1). Site index was not significant as a covariate in the analyses.

A complete preharvest inventory of all stems greater than 0.5 in. dbh in these stands allowed calculation of the basal area reduction resulting from the treatments. Regression of mean plot basal diameter and survival on basal area reduction (expressed as a percentage of initial plot basal area) resulted in significant simple linear models, with r^2 values of 0.63 and 0.40, respectively (Figures 1 and 2). The expected mean basal diameter of a population of advance red oak reproduction 9 years after, say, a 40% basal area reduction would be 0.35 in., and 50% of the initial population of 1-year old seedlings would have survived. The corresponding estimates assuming no basal area reduction would be 0.15 in. and 24%, respectively.

Georgia Study

Two plots received an incorrect treatment resulting in an unbalanced experiment; type III partial sums of squares from the General Linear Models procedure (SAS 1985) were used to test the significance of differences among treatment means ($P = 0.05$) in analyses of variance and covariance.

As in North Carolina, basal diameter growth of advance oak reproduction was increased by reducing basal area. Mean basal diameter growth in the 6 years since treatment ranged from 0.02 in. at 0% basal area reduction to 0.23 in. at 40% basal area reduction (Table 2). The difference between burned and unburned plots was not significant at the 0.05 level. Site index was significant as a covariate, with higher quality sites showing a greater increase in basal diameter growth than lower quality sites.

Survival of red oak seedlings did not differ significantly among the levels of basal area reduction, but burning significantly reduced survival (Table 3). Survival on unburned plots was 84%, but only 67% on burned plots. Site index was not a significant covariate for survival.

TABLE 1.

Effects of overstory reduction and understory elimination on basal diameter and survival of red oak seedlings 9 years after treatment at Bent Creek ($N = 13$ plots).

	Canopy treated		Canopy untreated	
Variable	Subcanopy treated	Subcanopy untreated	Subcanopy treated	Subcanopy untreated
Mean basal diameter (in.)	0.36	0.24	0.19	0.14
Survival (%)	50	44	25	22

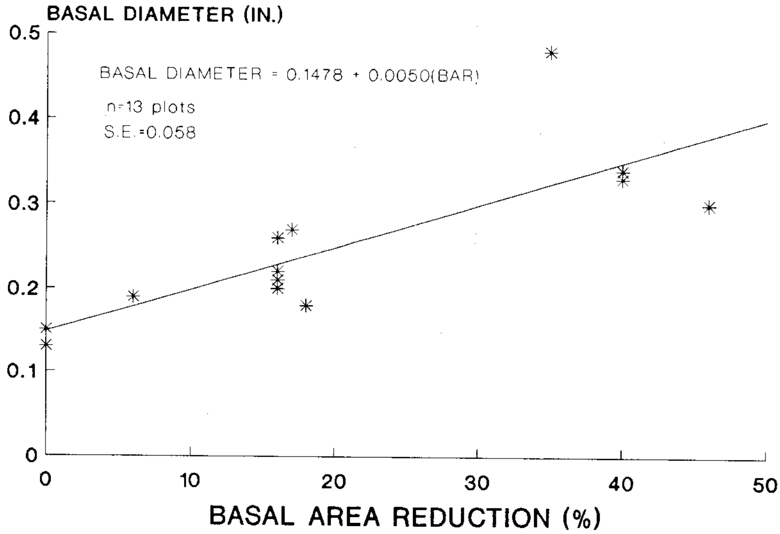

FIGURE 1. Relation between basal area reduction in mixed hardwood stands and mean basal diameter of red oak seedlings 9 years after treatment—13 Bent Creek plots.

To examine the impact of stand manipulation on development of tree species other than red oak, the change in the number of stems over 1 ft tall over the 6-year period since plot treatment was examined. This criterion was selected because populations of seedlings less than 1 ft tall can be quite transient and can vary considerably from year to year. Changes in the population of seedlings taller than 1 ft should be a better indicator of establishment and/or growth of regeneration resulting from the treatments after 6 years. Only at the 40% level of basal area reduction did large numbers of yellow-poplar become established and grow

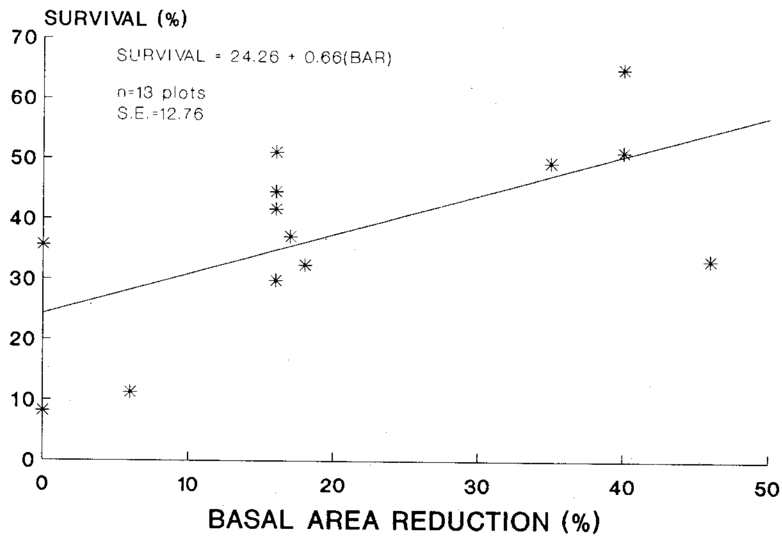

FIGURE 2. Relation between basal area reduction in mixed hardwood stands and survival of red oak seedlings on basal area reduction 9 years after treatment—13 Bent Creek plots.

TABLE 2.

Analysis of covariance and least squares (LS) means for 6-year basal diameter growth of red oak seedlings—Georgia plots ($N = 30$).

Basal area reduction (%)	LSMEANS (in.)	Burn treatment	LSMEANS (in.)
0	0.02		
10	0.08	unburned	0.16
20	0.14	burned	0.10
30	0.19		
40	0.23		
Prob $>F$ = 0.0008		Prob $>F$ = 0.0515	
Model R^2 = 0.73			

(Table 4). The interaction of burning treatment and basal area reduction was significant for the change in the number of yellow-poplar seedlings taller than 1 ft. The change in yellow-poplar on burned plots receiving a 40% basal area reduction was 8 times greater than that on the unburned plots receiving a 40% basal area reduction. Separate analyses of variance for burned and unburned plots indicates a significant change in yellow-poplar among levels of basal area reduction on burned plots. The differences are not significant on unburned plots. Despite the fact that site index was not a significant covariate, yellow-poplar became established and grew only on the highest quality sites.

The change in the number of stems of species other than red oak and yellow-poplar taller than 1 ft differed significantly among the levels of basal area reduction, but there was no difference between burned and unburned plots (Table 5). Site index was a significant covariate in the model with higher quality sites showing a greater change than lower quality sites. As expected, relatively shade-tolerant species such as red maple (*Acer rubrum* L.), dogwood (*Cornus florida* L.), and silverbell (*Halesia carolina* L.) increased in number. But commercial

TABLE 3.

Analysis of variance and least squares (LS) means for 6-year survival of red oak seedlings—Georgia plots ($N = 30$).

Basal area reduction (%)	LSMEANS (%)	Burn treatment	LSMEANS (%)
0	76		
10	67	unburned	84
20	83	burned	67
30	87		
40	64		
Prob $>F$ = 0.1403		Prob $>F$ = 0.0190	
Model R^2 = 0.55			

TABLE 4.

Analysis of variance and least squares (LS) means for 6-year change in number of yellow-poplar stems taller than 1 ft—Georgia plots (N = 30).

Basal area reduction (%)		LSMEANS Unburned	LSMEANS Burned	Means
		(No. of stems/ac)		
0		−117	−33	−75
10		0	−67	−33
20		−650	167	−242
30		−100	−33	−67
40		1100	8917	5008
	Means	47	1790	
		Model R^2 = 0.65		

species such as oaks (other than red oak), white ash (*Fraxinus americana* L.), basswood (*Tilia heterophylla* Vent.), black birch (*Betula lenta* L.), and hickories (*Carya* spp.) also increased in number.

Burning did not enhance basal diameter growth, did not control the development of other regeneration, and had an adverse impact on survival of red oak seedlings. Therefore, basal diameter growth, survival, and change in the number of competing stems on the 15 unburned plots only were analyzed using the linear regression of these response variables on the independent variables, site index, and percent basal area reduction (Table 6). Mean plot basal diameter growth increased significantly with increases in basal area reduction and increases in site index. Changes in the number of stems of species other than red oak and yellow-poplar taller than 1 ft increased with increasing basal area reduction. Neither red oak seedling survival nor changes in the number of yellow-poplar stems taller than 1 ft were significantly affected by changes in basal area or site index.

TABLE 5.

Analysis of covariance and least squares (LS) means for 6-year change in number of stems of species other than red oak and yellow-poplar taller than 1 ft—Georgia plots (N = 30).

Basal area reduction (%)	LSMEANS (No. of stems/ac)	Burn treatment	LSMEANS (No. of stems/ac)
0	−70		
10	601	unburned	3,126
20	2,717	burned	2,178
30	4,246		
40	5,765		
Prob >F = 0.0124		Prob >F = 0.3975	
	Model R^2 = 0.63		

TABLE 6.

Parameter estimates for linear regression of response variables on basal area reduction (BAR) and oak site index (SI)—unburned Georgia plots ($N = 15$).

Variable	b_0	b_1 (BAR)	b_2 (SI)	Model R^2
Mean basal diam. growth (in.)	−0.9083**	0.0064**	0.0117**	0.85
Survival (%)	54.94	0.39	0.25	0.10
Change in number of yellow-poplar	−7760	29	91	0.36
Change in number of others	−23160	177**	285	0.52

* Significant at 0.05 level.
** Significant at 0.01 level.

DISCUSSION

The results of these two studies clearly show that mature stands of Southern Appalachian hardwoods can be manipulated to enhance the development of red oak advance reproduction, thereby increasing the chances of maintaining a red oak component in new even-aged stands created by the eventual complete removal of the overstory.

There are two differences in the results from these studies that deserve explanation. First, site index was an important variable in the Georgia study, but not in the Bent Creek study. The most reasonable explanation for this difference is that site index ranged from 65 to 95 ft in the Georgia study, but only from 80 to 96 ft in the Bent Creek study. The second difference is that survival was significantly affected by basal area reduction in the Bent Creek study, but not in the Georgia study. Further, basal diameter growth was somewhat greater in the Georgia study than in the Bent Creek study. It appears that 1-year-old seedlings (Bent Creek study) respond somewhat differently to basal area reduction than do well-established seedlings that were characteristic of the Georgia study. Visual inspection of the seedlings in the Georgia study indicated that the seedlings had been established for at least several years—no acorns were attached. A test of the effect of initial seedling basal diameter on basal diameter growth after basal area reduction was not significant.

These differences do not alter the silvicultural prescription suggested by the studies. Reducing basal area from below, using herbicides, to 60%, 65%, and 70% of initial basal area on oak site indexes of 70, 80, and 90 ft, respectively, will provide stand conditions that will enhance the development of established red oak advance reproduction. From the regression presented in Table 6, these recommended levels of treatment would be expected to result in basal diameter growth of 0.17, 0.25, and 0.34 inches, respectively, 6 years after treatment. Despite the lack of significance in the test, yellow-poplar seedlings did become established and grow on the higher quality sites at the highest basal area reduction. It appears prudent, then, to reduce basal area less with increasing site index. This initial stand treatment should be done at least 10 years prior to anticipated harvest. The increase in basal diameter during this interval will enhance the competitive ability of the red oak advance reproduction at the time of harvest (Loftis 1988). With this large advance reproduction in place, either a final removal cut or a partial removal cut will result in the satisfactory development of red oak regeneration (Loftis 1983b).

It should be emphasized that the basal area reduction recommended above assumes that red oak reproduction is already established on the site. There is no evidence that this treatment will result in the establishment of new seedlings. If red oak advance reproduction is not present, underplanting may be feasible. Planting gives the silviculturist greater control of timing of silvicultural operations than waiting for seedlings to become established naturally. Underplanting has been recommended in the Ozarks for oaks (Johnson et al. 1986), and is currently being tested in the Southern Appalachians.

The application of herbicides prior to the harvest of mature Southern Appalachian hardwood stands is not a new idea. Previous work has shown that treating unmerchantable, primarily shade-tolerant vegetation 1 to 3 years prior to clearcutting results in a better stand of regeneration than does felling this same unmerchantable vegetation after clearcutting (Loftis 1978, 1985). This is the same vegetation that would be treated in an oak shelterwood. Recent preharvest herbicide treatments on National Forests have cost $60 per acre,[1] about the same as the cost of post-harvest felling of unmerchantable vegetation. The difference between preharvest herbicide treatment as an alternative to post-harvest felling and preharvest treatment as the initial operation in an oak shelterwood is essentially a difference in the timing of treatment application.

Despite the presumed historical importance of fire in altering species composition, the single prescribed burn applied in this study does not appear to be a very promising technique for regenerating red oak on high-quality sites. Prescribed burning adversely affected red oak survival, and basal diameter growth was less (though not significantly so) on burned than on unburned plots. Another drawback to the use of prescribed fire on these relatively moist sites is simply being able to burn in a timely manner.

What was the origin of mature second-growth even-aged and two-aged stands in which red oak is a prominent component? Based on current knowledge, one could argue that large advance reproduction of red oak must have been present when the heavy cutting of major logging operations created these second-growth stands in the period from about 1900 to 1940. A precise knowledge of the pattern of land use in the Southern Appalachians preceding this cutting is obscured by time. Fire, used in conjunction with livestock grazing and for other purposes, was a common, and in some cases, annual occurrence. The annual use of wood for fuel and for construction in the subsistence homestead was substantial and probably created a variety of stand conditions (Nesbitt 1941). When these disturbances coincided with the presence of advance oak reproduction, it is likely that stand conditions were conducive to the development of the advance reproduction. The large advance reproduction that developed was then released by the very heavy cutting of major logging operations.

Another disturbance factor in the 1920s and 1930s was the demise of the

[1] Personal communication, Gary Willison, Pisgah Ranger District, Pisgah National Forest, NC.

American chestnut. This disturbance could also have created understory conditions favoring the development of large red oak advance reproduction. In addition, the death of chestnut sprouts in young stands created by heavy cutting could have released red oak reproduction which would have otherwise been suppressed.

If one compares the disturbance regime that preceded the creation of current second-growth stands with the disturbance regime that precedes the creation of even-aged stands today, failure to maintain a red oak component in new stands is not surprising. Fire and grazing are no longer important factors in the Southern Appalachian forests. Perhaps more important, current second-growth stands, particularly on National Forests, usually experience no significant disturbance for decades prior to harvest. Dense canopies and subcanopies develop. Consequently, large advance reproduction of red oak does not develop, and red oak is not a component of new stands created by clearcutting or heavy shelterwood cuts.

The silvicultural technique recommended in this paper to regenerate red oak is only one of several possibilities, but it is the only one that has been tested thoroughly enough to recommend. It is also one that can be integrated into current even-aged management schemes, and, possibly, into the group selection method. The applicability of this technique beyond the Southern Appalachians is not known. The typical well-stocked, mature hardwood stand on higher quality sites in the Southern Appalachians is a layered plant community, with oaks or mixtures of other deciduous species comprising the main canopy. The subcanopy is comprised primarily of shade-tolerant, noncommercial species, and will usually contain 15%–30% of total stand basal area—the basal area of all stems greater than 1 in. dbh. The silvicultural practice recommended in this paper essentially eliminates subcanopy layers, leaving the main canopy mostly intact with no large gaps. To the extent that other forest types containing oaks have a similar structure, this technique might work, with modifications in basal area reduction dictated by differences in the response of the various oak species.

Another possible difference between the Southern Appalachians and other deciduous forest regions is in oak seedling establishment. Whenever there is a "bumper" crop of red oak acorns in the Southern Appalachians, new seedlings are usually abundant the following Spring. This does not appear to be the case in some other deciduous forest regions. The specific impediments to establishment must be identified and dealt with as problems distinct from that of determining the level of stand disturbance necessary to enhance the growth of established oak seedlings. If, for example, the deer population is so high that all acorns or new seedlings are consumed, some way to reduce predation of acorns or seedlings will have to be found. Once oak seedlings are established, the silvicultural practice recommended here, or some modification determined by further research, will probably result in the development of large advance reproduction.

CONCLUSIONS

It is possible to disturb mature Southern Appalachian stands in a way that stimulates growth of established red oak advance reproduction, increasing its chances of competing successfully after overstory removal. Reducing stand basal area from below by applying herbicides provides the conditions necessary for red oak advance reproduction to grow, and it removes a source of sprout competition that would otherwise be present after a harvest cut. The recommended reduction in basal area varies inversely with site index. The smaller reduction on higher quality sites prevents yellow-poplar from becoming established and growing prior to the final removal cut. The interval between this herbicide treatment and the subsequent removal cut(s) will be at least 10 years. This shelterwood method appears to be cost effective when compared to the current practice of clearcutting, which includes control of undesirables before or after harvest.

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