GROWTH OF OAK, ASH, AND CHERRY REPRODUCTION FOLLOWING OVERSTORY THINNING OF UPLAND HARDWOOD STANDS IN THE BOSTON MOUNTAINS OF ARKANSAS[1]

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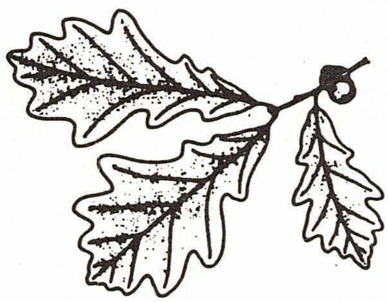

ABSTRACT.--A study of reproduction growth following thinning in mixed upland hardwood stands was initiated in the Boston Mountains of Arkansas in the spring of 1976. Sixty-four plots, representing a wide range in initial stand age and site quality, were thinned to residual overstory densities ranging from less than 40 percent to over 100 percent relative stocking density. Subcanopy stems in all thinned stands were partially controlled by cutting. Growth of established oak (*Quercus alba* L., *Q. velutina* Lam., and *Q. rubra* L.), white ash (*Fraxinus americana* L.), and black cherry (*Prunus serotina* Ehrh.) advance reproduction was monitored for 5 years following thinning. In nonthinned stands, total oak, ash, and cherry reproduction averaged 3,000 stems per acre; but fewer than 300 per acre were taller than 1 foot, and only 15 stems exceeded a height of 5 feet. In thinned stands, total oak, ash, and cherry reproduction had not changed significantly in the 5 years; however, the number of stems taller than 1 foot had increased to about 1,000 per acre. Stems taller than 5 feet ranged from 90 per acre with the light thinning treatment to nearly 300 per acre in the heavily thinned stands. Five-year height growth of established oak, ash, and cherry reproduction increased significantly with intensity of overstory thinning. Ash and cherry produced maximum height growth on good to excellent sites, while oaks grew well on all sites.

INTRODUCTION

Mixed oak types comprise most of the commercial forest land in northern Arkansas, and oaks are the dominant timber species throughout this region. Valuable, fast-growing, intolerant species such as yellow-poplar (*Liriodendron tulipifera* L.) do not occur in the upland mixed oak areas, and other desirable species such as black walnut (*Juglans nigra* L.), black cherry (*Prunus serotina* Ehrh), and white ash (*Fraxinus americana* L.) occur only sporadically and only on the better sites. Most associated species in these upland stands are either slower growing or of lower value than the oaks, so it is important that present stands are regenerated to oak following harvest.

Research has shown that the oak component of young hardwood stands following complete overstory removal will be proportional to the number and size of oak advance reproduction present at the time of overstory removal (Sander 1971, 1972). Newly established oak seedlings and small advance reproduction grow much too slowly to compete successfully

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following harvest (Sander and Clark 1971; McQuilkin 1975), while large stems of oak advance reproduction grow rapidly after harvest and have a higher probability of becoming dominant in the new stands (Carvell 1979; Sander 1971, 1972).

Upland hardwood stands in the Boston Mountains of northern Arkansas may have several thousand reproduction stems per acre of oak and other desirable species that are less than 1 foot tall, but large reproduction is sparse or completely absent. Many of these stands are within 30 years of rotation age and are fully stocked--but have well-developed understories that consist primarily of tolerant noncommercial species. Given the present size and status of existing reproduction, the new reproduction stand following final overstory removal will contain a mixture of species but will almost certainly contain a low proportion of oak. To enhance development of established oak advance reproduction in such stands, a shelterwood system (Sander 1979, 1983; Loftis 1983a, 1983b; Gottschalk 1983) involving light to medium overstory removals coupled with partial to complete understory control is being evaluated for upland oak stands in several areas.

This paper presents the 5-year height-growth response to overstory thinning in oak stands where understories were partially controlled by cutting. The advance reproduction favored in these stands consisted of oaks (northern red, black, and white), white ash, and black cherry.

METHODS

A series of 64 plots, installed on Ozark National Forest lands as part of an oak growth and yield study (Graney 1980), provided an opportunity to study effects of stand density on establishment and growth of oak, ash, and cherry reproduction.

Each plot was approximately 1 acre in size (0.4- or 0.5-acre measurement plot plus a 33-foot buffer strip treated the same as the plot). The 64 plots represented ranges in stand age from 35 to 75 years with site index (base age 50 years for northern red or black oak) from 45 to 84 feet. There were four overstory thinning treatments: 40 percent, 60 percent, and 80 percent (relative stocking density, Gingrich 1967), and a nonthinned control. Pretreatment stocking densities for all plots averaged about 107 percent for trees larger than 2.5 inches d.b.h., and initial basal areas averaged about 111 square feet per acre. The understory subcanopy was well developed on all study plots. Small trees (0.6 to 2.5 inches d.b.h.) averaged more than 600 stems per acre and contributed an additional 6 square feet of basal area and 13 percent stocking on study plots.

The majority of the overstory density treatments in these intermediate-aged stands was accomplished by thinning mostly from below. Culls and poor quality trees were removed first, then intermediate and suppressed trees of low quality and vigor. Residual stands generally contained the better dominants and codominants as uniformly distributed as possible, although it was necessary to leave some midstory stems on plots receiving the 80 percent stocking treatment. Overstories on all plots were predominately oak. Northern red, black, and white oaks accounted for more than 90 percent of the overstory basal area before thinning and more than 95 percent after thinning. Although often a major component of the advance regeneration in most stands, ash and cherry represented less than 1 percent of the overstory stocking on all plots.

Plot understories were dominated by tolerant, brushy, or less desirable species such as red maple (Acer rubrum L.), serviceberry (Amelanchier arborea (Michx. f.) Fern.), redbud (Cercis canadensis L.), and blackgum (Nyssa sylvatica Marsh.) on poor to medium sites, while dogwood (Cornus florida L.), hophornbeam (Ostrya virginiana (Mill.) K. Koch), pawpaw (Asimina triloba (L.) Dunal), and sugar maple (Acer saccharum Marsh.) were most common on good sites. The number of small trees was highly variable and ranged from fewer than 300 per acre in some stands (site index 50), to more than 1,000 per acre in other stands (site indexes 70 and 80). To make the initial contribution of small trees as uniform as possible across all treated plots, the number of trees in the 0.6- to 2.5-inch d.b.h. classes was reduced to about 200 per acre (approximately 4 percent stocking). Throughout the period of plot establishment and treatment, the Ozark National Forest was restricted from use of all herbicides, therefore it was necessary to manually cut individual stems.

Reproduction was measured on a series of fourteen to sixteen 2-milacre circular subplots systematically distributed across each plot. On each subplot, all regeneration up to 2.5 inches d.b.h. was tallied by species, origin (true seedling, seedling sprout, or sprout from a cut stem), and total height to the nearest 1-foot class. For all oak, ash, and cherry reproduction, total height and height growth since treatment were measured to the nearest 0.1 foot.

The study was designed as a balanced factorial arrangement with four age classes (40, 50, 60, and 70 years), four site index classes (50, 60, 70, and 80 feet), and four stocking treatments (40 percent, 60 percent, 80 percent, and nonthinned). There were no replications. Separate analyses were completed for oak, ash plus cherry, and other species data sets. Data were analyzed using analysis of variance to test for differences in main effects and 2-factor interactions, with the 3-factor interaction serving as the error term in all analyses. Duncan's multiple range tests were used to compare individual treatment means.

RESULTS

Advance Reproduction in Nonthinned Stands

The height distribution of oak, ash, and cherry reproduction in the 16 nonthinned stands is fairly typical of reproduction under nonthinned intermediate-aged upland oak stands in the Boston

Mountains (table 1). Although the amount of oak reproduction would appear to be more than adequate to replace existing stands, large advance reproduction (taller than 4 or 5 feet) is often sparse or (as in this case) absent. Most of the oak reproduction is less than 1 foot tall, with relatively few stems taller than 2 feet. Ash and cherry reproduction is highly variable throughout the Boston Mountains but is usually most abundant on medium to good sites. Although ash and cherry will collectively contribute less than 1 percent of the overstory in most stands, they often represent the majority of the advance reproduction of desirable species taller than 2 feet, and nearly all of the desirable species reproduction taller than 5 feet (table 1).

TABLE 1.--Mean height distribution of oak, ash, and cherry reproduction stems per acre in nonthinned oak stands.

Species	Height Class (Feet) <1.1	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	>5.0
	Number of Stems					
Oaks[1]	1660	63	23	3	0	0
Ash + cherry	958	126	30	10	4	15

[1] white, black, and northern red oaks

Reproduction After Treatment

EFFECTS OF RESIDUAL STOCKING.--After 5 years, total oak, ash, and cherry reproduction and number of small stems less than 1 foot in height in thinned stands did not change significantly, although there were generally fewer small stems in the heavily thinned stands. However, there were significantly more stems in the 1.1- to 5.0-foot and taller than 5.0-foot height classes than in the nonthinned stands. Stands thinned to 40 or 60 percent stocking contained the greatest number of oaks taller than 1 foot. Ash and cherry stems 1.1 to 5.0 feet were about the same under stands thinned to 40 or 60 percent stocking, but the number of stems taller than 5 feet was significantly greater under stands with 60 percent stocking (table 2).

Although the amount of oak, ash, and cherry reproduction taller than 1 foot increased significantly after thinning, the actual number of stems is small when compared to the increase in competing stems of other species. Stems of other species increased from about 5,000 per acre in nonthinned stands to 8,000 to 10,000 in thinned stands. Of the 3,000 to 5,000 stems per acre taller than 5 feet, more than 1,000 per acre (primarily red maple sprouts) averaged 10 to 20 feet after 5 years (table 2).

EFFECTS OF SITE INDEX.--The relationships between site index and quantity of reproduction varied considerably by species and reproduction size. The number of small stems for all species was lowest on the best Boston Mountain sites. Stands on poor sites generally contained significantly fewer stems of ash, cherry, and other species in all height classes (table 2).

Total oak reproduction was greatest under site index 60 stands, while the number of oak stems taller than 1 foot was greater in stands with a site index of 50. Ash and cherry reproduction taller than 1 foot was most numerous in site index 70 stands, and was about equal in the stands with site indexes of 60 and 80.

TABLE 2.--Reproduction 5 years after thinning as affected by residual stocking, site index, and stand age.

Species and Height	Residual Stocking (Percent) N.T.[1]	80	60	40	Site Index (Feet) 50	60	70	80	Stand Age (Years) 40	50	60	70
	Number of Stems per Acre											
Oaks[2]												
<1.1 ft	1660a	1346a	1470a	1280a	1500b[3]	2091c	1291b	874a	1293a	1260a	1692a	1511a
1.1-5.0 ft	89a	210b	340c	340c	335c	262b	227b	154a	299a	240a	267a	173a
>5.0 ft	0a	41b	94c	91c	95b	57a	47a	27a	71a	63a	60a	30a
Ash + cherry												
<1.1 ft	958a	749a	785a	516a	288a	1263b	1019b	438a	624a	815a	784a	785a
1.1-5.0 ft	170a	360b	471c	558c	109a	391b	731c	327b	291a	442a	443a	382a
>5.0 ft	15a	48b	75b	189c	16a	87b	120b	105b	42a	92a	89a	106a
Other species												
<1.1 ft	2854b	2986b	2202b	1736a	2160a	2949b	2724b	1945a	2086a	1836a	2918b	2938b
1.1-5.0 ft	3695a	5676b	5472b	5046b	3439a	5575b	5151b	2752b	3875a	4435a	4567b	6111b
>5.0 ft	1495a	2629b	3718c	4852d	1863a	3160b	3824b	4347c	2396a	3145b	3333b	3821b

[1] N.T. = nonthinned
[2] white, black, and northern red oaks
[3] means in rows within stocking, site index, or age treatments followed by the same letter are not significantly different at the 0.05 level

Reproduction of other species taller than 1 foot was about the same on medium to high sites; although the number of stems exceeding 5 feet in height was significantly greater in the site index 80 stands.

EFFECTS OF STAND AGE.--Stand age, through the range of 35 to 75 years, had little influence on the amount of oak, ash, and cherry reproduction. The number of reproduction stems of other species was greatest in the older stands (table 2), which indicated the buildup of a shade-tolerant subcanopy under the Boston Mountain stands with increasing stand age.

Two-factor interactions between stocking, site index, and age were significant in three analyses, but generally indicated high or low values for a given stocking/site index or site index/age combination, and did not alter the main effect relationships mentioned above and shown in Table 2.

Height Growth 5 Years After Treatment

Oak, ash, and cherry seedlings established following the overstory treatments produced little or no additional growth after the first year. Average total height for all first- to fifth-year seedlings was about 0.5 foot (table 3).

TABLE 3.--Total height of oak, ash, and cherry seedling reproduction established during the 5-year period following treatment.

Species	Residual Stocking (Percent) N.T.[1]	80	60	40
	Feet			
Oaks[2]	0.4	0.4	0.5	0.5
Ash + cherry	0.4	0.5	0.6	0.6

[1] N.T. = nonthinned
[2] white, black, and northern red oaks

Growth of older oak seedlings was also relatively slow over the 5-year period but was slightly greater under the medium to heavily thinned stands and on the better sites (table 4).

Older ash and cherry seedlings responded significantly to overstory thinning and changes in site quality. Five-year growth of seedlings in stands thinned to 80 percent stocking was more than twice as great as that of seedlings in nonthinned stands, while height growth of ash and cherry seedlings in the more heavily thinned stands was three times greater than those in the nonthinned stands (table 4). Across all stocking treatments, height growth was significantly greater where site indexes were 70 and 80.

Sprout reproduction showed the greatest increase in height over the 5-year period. Oak sprouts grew best under stands thinned to 40 percent stocking, and averaged about the same growth on all site indexes (table 4). Heights of ash and cherry sprouts increased significantly with intensity of overstory thinnings, and sprouts in stands thinned to 40 percent stocking averaged 3 feet more height growth than sprouts in the nonthinned stands. Height growth of ash and cherry sprouts also increased significantly with increasing site index, with the greatest increase occurring in the site index 80 stands.

Neither stand age nor the two-factor interactions for stocking, site, and age were significant in the oak, ash, and cherry height growth analyses.

TABLE 4.--Average 5-year height growth of oak, ash, and cherry reproduction established prior to treatment as influenced by residual stocking and site index.

Species	Residual Stocking (Percent) N.T.[1]	80	60	40	Site Index (Feet) 50	60	70	80
	Feet							
Oak seedlings[2]	0.3a[3]	0.4a	0.6b	0.6b	0.4a	0.4a	0.6b	0.6b
Ash + cherry seedlings	0.5a	1.2b	1.6c	1.7c	0.8a	1.2b	1.7c	1.5c
Oak sprouts[2]	0.4a	1.3b	1.7b	2.3c	1.6a	1.4a	1.3a	1.5a
Ash + cherry sprouts	0.7a	2.1b	3.0c	3.8d	1.4a	2.3b	2.4b	3.5c

[1] N.T. = nonthinned
[2] white, black, and northern red oaks
[3] means in rows within stocking and site index treatments followed by the same letter are not significantly different at the 0.05 level

DISCUSSION

A primary objective in using the shelterwood system in upland oak stands is to enhance the growth of small established oak reproduction so the reproduction will be competitive in the new stand after final harvest. Under the overstory and partial understory control treatments implemented in this study, all stocking treatments resulted in an increase in the average size of oak, ash, and cherry reproduction when compared with reproduction in nonthinned stands. The number of oaks taller than 1 foot increased from fewer than 100 per acre in nonthinned stands to more than 400 per acre in the stands thinned to 40 and 60 percent stocking. At the same time, ash and cherry averaged between 200 and 500 more stems per acre than observed for nonthinned stands. Most of the increase resulted from smaller stems growing into the 1.1- to 4.0-foot classes (table 5). However, as illustrated by the height distributions for stands thinned to 40 and 60 percent stocking, number of stems growing into the taller height classes was strongly influenced by site quality (table 6). The number of oak stems taller than 2 feet was greatest in the site index 50 stands and declined with increasing site index. This resulted in the Boston Mountain sites with the greatest potential for growth producing the fewest stems in all height classes. On the other hand, the number of ash and cherry stems under the 40 and 60 percent stocked stands was very low on poor sites and highest on medium to good sites (table 6).

TABLE 5.--Mean height distribution of oak, ash, and cherry reproduction stems 5 years after treatment.

Species	Residual Stocking	Height Class (Feet) <1.1	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	>5.0
	-Percent-	----Number of Stems per Acre----					
Oaks[1/]	N.T.[2/]	1660	63	23	3	0	0
	80	1346	120	44	35	11	41
	60	1470	154	97	60	29	94
	40	1280	188	70	50	32	91
Ash + cherry	N.T.	958	126	30	10	4	15
	80	749	247	77	22	14	48
	60	785	265	116	56	34	75
	40	516	298	148	72	40	189

1/ white, black, and northern red oaks
2/ N.T. = nonthinned

TABLE 6.--Mean height distribution of oak, ash, and cherry reproduction stems 5 years after treatment for stands thinned to 40 and 60 percent stocking.

Species	Site Index	Height Class (Feet) <1.1	1.1-2.0	2.1-3.0	3.1-4.0	4.1-5.0	>5.0
	--Feet--	----Number of Stems per Acre----					
Oaks[1/]	50	1623[2/]	148	136	72	71	154
	60	2022	198	94	66	23	96
	70	1309	210	58	49	18	81
	80	547	126	48	33	10	38
Ash + cherry	50	152	65	14	5	5	22
	60	1226	380	138	52	23	126
	70	843	514	238	141	93	154
	80	382	168	139	60	26	178

1/ white, black, and northern red oaks
2/ mean number of stems for stands thinned to 40 percent and 60 percent stocking

For all stocking treatments, most of the oak reproduction taller than 4 feet developed from stump sprouts, primarily in the 40- to 60-year-old stands on medium to poor sites. No oak stump sprouts were recorded in the 70-year-old stands with site indexes 70 and 80. Based on prethinning diameter distributions for plots representing 70- to 80-year-old stands with site indexes of 70 and 80, predicted stump sprouts (Johnson 1977; Sander et al. 1976) for black, northern red, and white oaks should average about 40 stems per acre. Therefore, continued development of small oak reproduction into the larger size classes is imperative for regenerating existing stands to predominately oak.

Ash and cherry reproduction taller than 4 feet developed primarily from extended growth of established seedlings and from seedling sprouts. Although representing fewer than 10 stems per acre, ash and cherry stump sprouts attained average 5-year heights of 10 feet. Some sprouts in site index 80 stands exceeded 20 feet, and were the only desirable reproduction stems that were competitive with red maple sprouts in these stands.

While overstory and understory treatments imposed in this study resulted in significant increases in the number of oak, ash, and cherry stems taller than 1 foot, the average 5-year increase in height for established reproduction, particularly oaks, was relatively small. Older oak seedling reproduction under thinned stands averaged about 0.1 foot of height growth per year, while sprouts averaged 0.2 to 0.5 foot per year, depending on overstory density. Nearly all of the oak seedling and seedling sprout reproduction present at the time of thinning was less than 1 foot tall, averaging 0.3 to 0.5 foot. Although based on relatively few stems, response of established reproduction taller than 1 foot at the time of treatment indicated somewhat greater increases in height (table 7). Five-year height increases under stands thinned to 40 or 60 percent stocking averaged more than 2.5 feet for the taller oak seedlings, while increases for ash and cherry averaged about 3.5 feet. Oak seedling sprouts originating from existing stems taller than 1 foot grew about 3.5 feet, while ash and cherry seedling sprouts averaged about 4-foot and 5-foot increases in stands thinned to 60 and 40 percent overstory stocking, respectively. Stump sprouts were the tallest reproduction for each species group. Five-year heights of oak stump sprouts averaged 4.5 feet in stands thinned to 80 percent stocking and more than 5.5 feet in stands thinned to 40 or 60 percent. Average heights of ash and cherry sprouts increased with intensity of overstory thinning and ranged from about 8 feet in stands thinned to 80 percent stocking to more than 13.5 feet under stands thinned to 40 percent overstory stocking.

TABLE 7.--Average 5-year height growth of oak, ash, and cherry reproduction taller than 1 foot at the time of treatment or sprouting from a cut or established stem taller than 1 foot.

Species and Type of Reproduction	Residual Stocking Percent N.T.[1/]	80	60	40
	----Feet----			
Seedlings				
Oaks[2/]	0.7	1.4	2.6	2.8
Ash + cherry	1.2	1.9	3.4	3.8
Seedling sprouts				
Oaks	-	1.8	3.4	3.4
Ash + cherry	-	2.7	4.1	4.9
Stump sprouts				
Oaks	-	4.5	5.7	5.6
Ash + cherry	-	7.9	9.8	13.6

1/ N.T. = nonthinned
2/ white, black, and northern red oaks

The partial understory control treatment (reducing the number of stems in the 0.6- to 2.5-inch d.b.h. classes to 200 per acre by cutting) was probably the least desirable method of control, but represented the only alternative due to the ban on herbicide application. Pretreatment heights of stems in the 0.6- to 2.5-inch diameter classes averaged more than 25 feet, and on most plots represented a secondary closed canopy of shade above the small oak, ash, and cherry reproduction. In such stands, overstory thinning alone will often have no appreciable effect on the amount of light reaching the forest floor. The understory treatment significantly increased light penetration to the forest floor for a period of at least 3 years and resulted in some improvement through the 5-year period. However, 5 years following thinning, the number of competing stems taller than 1 foot had nearly doubled, and stems taller than 5 feet were nearly three times greater than in nonthinned stands. The number of competing stems increased with intensity of overstory thinning and was generally greatest under the older stands on medium to good sites. Competition under stands thinned to 40 percent with site indexes of 70 and 80 was further increased by a surge of herbaceous vegetation dominated by blackberry (Rubus spp.). This vegetation also competes with the small reproduction and may seriously affect survival of newly established seedlings. The number of small oak, ash, and cherry stems was generally much lower under the medium to heavily thinned stands on the better sites (table 6).

While removal of most of the large subcanopy stems by cutting was of some benefit to small reproduction, the increase in light reaching the forest floor will be short-lived. As sprouts from the cut understory continue to increase in height and smaller competing reproduction continues to develop, the small oak reproduction will be overtopped by less desirable species during the next 5 years, and will require at least one additional control treatment before an adequate number of desirable stems reach the minimum size to be competitive at final harvest.

Response of oak, ash, and cherry reproduction to overstory density and partial understory control treatments imposed in this study indicates that the shelterwood system will be effective in the Boston Mountain area. However, responses observed in this study, where understory control was temporary, are possibly not indicative of potential responses had the subcanopy (large and small stems) been effectively controlled with herbicides to prevent sprouting. Studies to evaluate the effects of overstory density reduction with effective control of various sizes of subcanopy stems are presently underway in the Boston Mountain area.

CONCLUSIONS

The initial 5-year growth response following treatments suggest that:

1. The shelterwood system, combined with partial understory control, should be an effective system to enhance development of established desirable reproduction in upland oak stands in the Boston Mountains. After 5 years, the number of oak, ash, and cherry stems taller than 1 foot was significantly greater in treated stands than in the nonthinned controls. Ash and cherry generally produced a greater height growth response to the overstory treatments than did the oak. The partial understory control with a hand-cutting treatment on thinned plots decreased the level of subcanopy shade and, possibly, was of some temporary benefit to small reproduction. However, rapid development of the nontreated understory and growth of sprouts from cut stems have, after 5 years, more than doubled the number of competing stems per acre, and these sprouts have mostly overtopped the small oak, ash, and cherry reproduction. To maintain development of desirable reproduction, an additional understory control treatment would be necessary. Effective control of the subcanopy with herbicides would have reduced the sprout competition and would possibly eliminate the need for a second subcanopy treatment. Effective control of the subcanopy is especially critical in the older stands on better sites where small trees in 1- and 2-inch diameter classes often exceed 1,000 per acre and are primarily tolerant species that sprout vigorously.

2. A residual overstory stocking density of 60 percent seems adequate to achieve development of established oak, ash, and cherry reproduction. Leaving a residual overstory density of 80 percent generally reduced height growth of oak, ash, and cherry seedlings and sprouts and did not obviously reduce numbers of competing stems. Thinning to 40 percent stocking would increase development of ash, cherry, and competing reproduction but would not significantly increase growth of the oak reproduction. In stands thinned to 60 percent stocking, ash and cherry are present in adequate numbers, are still outgrowing the oaks, and will most likely become a significant component in the stands following harvest. There seems to be little advantage to leaving an understocked situation over the 10-year or longer period that will apparently be required for development of adequate numbers of large oak advance reproduction in these stands.

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