GROWTH OF OAK, ASH, AND CHERRY REPRODUCTION FOLLOWING OVERSTORY THINNING AND UNDERSTORY CONTROL IN UPLAND HARDWOOD STANDS OF NORTHERN ARKANSAS[1/]

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Abstract.--A study of reproduction growth following overstory thinning and understory control in mixed upland hardwood stands was initiated in the Boston Mountains of Arkansas in the spring of 1980. Thirty-six plots representing mature upland hardwood stands on medium- to high-quality sites were thinned to residual overstory densities of 40- to 60-percent relative stocking density. Subcanopy stems were partially or completely controlled with herbicide applications. Growth of oak (Quercus alba L., Q. velutina Lam., and Q. rubra L.), white ash (Fraxinus americana L.), and black cherry (Prunus serotina Ehrh.) reproduction was monitored for 5 years following treatments. Before treatment, total oak, ash, and cherry reproduction averaged 3,000 stems per acre with a mean height of less than 1 foot, and there were fewer than 10 stems per acre taller than 5 feet. After treatment, growth of oak reproduction increased with the intensity of understory control, while ash and cherry grew best under the 40-percent overstory stocking treatment.

INTRODUCTION

Mixed oak types occupy most of the commercial forest land in northern Arkansas, and oaks are the dominant timber species throughout this region. Valuable, fast-growing species such as yellow-poplar (Liriodendron tulipifera L.) do not occur in western Arkansas, and desirable species such as black walnut (Juglans nigra L.), black cherry (Prunus serotina Ehrh), and white ash (Fraxinus americana L.) occur only sporadically, primarily 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 to insure that oaks will be a significant component of new stands following harvest.

Research has shown that the oak component of young hardwood stands will depend on sprouts from cut overstory stems and 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 too slowly to compete successfully following harvest (Sander and Clark 1971; McQuilkin 1975). However, large oak advance reproduction grows rapidly after harvest and has a greater probability of becoming dominant in the new stand (Carvell 1979; Sander 1972; Sander and others 1984).

Upland hardwood stands in the Boston Mountains of northern Arkansas may have several thousand stems per acre of oak and other desirable species that are less than 1 foot tall, but large reproduction, especially oak, is sparse or absent. Many of these stands are within 30 years of rotation age, and fully stocked, and have well-developed understories composed of tolerant noncommerical species. Given the present size and status of existing reproduction, the new reproduction stand following 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 1983, 1985; Gottschalk 1983) with light to medium overstory removals and partial to complete understory control is being evaluated for upland oak stands in several geographic areas.

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In this paper, the 5-year height growth response of oaks (northern red (*Quercus rubra* L.), black (*Quercus velutina* Lam.), and white (*Quercus alba* L.), black cherry, and white ash advance reproduction are related to overstory and understory density control in mature upland hardwood stands in the Boston Mountains of northern Arkansas.

METHODS

Six stands of mature upland hardwoods were chosen for this study from Ozark National Forests lands in the Boston Mountains of northern Arkansas. Three stands were located on upper north- or east-facing slopes representing medium oak sites (50-year site index = 60 ft for northern red oak), and three stands were located on north- or east-facing mountain benches representing excellent oak sites (50-year site index >75 ft for northern red oak). Six plots (approximately 1 acre in size) were established in each stand, and one of six overstory-understory treatments was randomly assigned to each plot. Overstory (stems ≥1.6 inches in d.b.h.) densities were thinned to either 40 percent or 60 percent relative stocking density (Gingrich 1967). Understory (stems <1.6 inches in d.b.h.) treatments were: (1) treat all nondesirable stems, (2) treat all nondesirable stems taller than 5 ft, or (3) no understory treatment. Desirable species were oaks, ash, cherry, and black walnut.

Pretreatment overstory stocking densities for all plots averaged 106 percent with a mean basal area of about 118 ft^2 per acre (table 1). Overstory density treatments were accomplished by thinning mostly from below. All subcanopy stems 1.6 inches and larger in d.b.h. were removed first, then the overstory canopy was thinned to the prescribed stocking goal. Stumps of all nondesirable overstory stems were treated with a herbicide spray (2,4-D + picloram) immediately after felling to reduce sprouting. Overstories on all plots were predominantly oak. Northern red, black, and white oaks accounted for more than 80 percent of the overstory before thinning and more than 90 percent after treatment. Ash and cherry represented less than 1 percent of the stocking on all plots.

Understories on study plots were well developed and consisted of 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 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 common on good sites. Understory control treatments were accomplished by cutting all stems near ground level and spraying all stumps with herbicide (2,4-D + picloram) immediately after cutting. Understory treatments were completed in May 1980 and overstories were thinned in June and July of 1980.

Reproduction was measured on a series of sixteen 1/735-acre circular subplots systematically distributed across the interior 0.25 acre of each plot. On each subplot, all regeneration up to 1.5 inches in d.b.h. was tallied by species, origin (true seedling, seedling sprout, or sprout from a cut stem), and total height. For all oak, ash, and cherry reproduction, stem age, basal diameter to the nearest 0.1 inch and total height to the nearest 0.1 ft were also recorded. Reproduction was measured before treatment and after the first, third, and fifth years following treatments.

The study design was a randomized block. Data were analyzed using analysis of variance to test for differences in main effects. Duncan's multiple range tests were used to compare individual treatment means.

RESULTS

Advance Reproduction Before Treatement

The pretreatment height distribution of advance reproduction on study plots is typical of nonthinned mature upland oak stands in the Boston Mountains (table 2). Total oak, ash, and cherry

Table 1.--Stand characteristics per acre before and after treatment for trees 1.6 inches and larger in d.b.h.

Stocking treatment	Original Stand: Number of trees	Original Stand: Basal area	Original Stand: Stocking	Residual Stand: Number of trees	Residual Stand: Basal area	Residual Stand: Stocking
		ft.^{2}	percent		ft.^{2}	percent
Site index = 60 ft						
40 percent	464	118	108	57	52	40
60 percent	413	121	108	82	73	60
Site index = 75 ft						
40 percent	413	114	103	54	53	40
60 percent	424	118	106	70	74	59

Table 2.--Mean height distribution per acre of oak, ash, and cherry reproduction stems before treatment

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					
Site index = 60						
Oaks 1/	1959	106	15	13	5	0
Ash and cherry	930	222	143	72	41	5
Other species	4341	2910	1346	1187	905	1569
Site index = 75						
Oaks	1243	61	18	8	5	0
Ash and cherry	452	179	74	38	31	5
Other species	4813	2387	1523	1153	1160	1408

1/White, black, and northern red oaks.

reproduction and advance reproduction taller than 1 ft are greatest on the less productive upland sites. Although the number of oak reproduction stems are high, tall advance reproduction (>5 ft) is often sparse or absent. Most of the oak reproduction is less than 1 ft tall, and few stems are taller than 2 ft. 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 are minor components of the overstory in most stands, they represent the majority of the desirable species' advance reproduction taller than 2 ft (table 2).

The other species group (table 2) is dominated by the tolerant, brushy, and noncommercial species, but also includes the hickories (*Carya* spp.) and other less common species that would be considered acceptable for stocking on selected sites.

Reproduction After Treatment

Effects of Site Index.--Neither abundance, growth, nor mortality of pretreatment advance reproduction over the 5-year period was significantly related to site quality. The amount and survival of new reproduction was not influenced by site index either.

Effects of Overstory Density.--While total oak, ash, and cherry reproduction and number of stems taller than 1 ft increased following thinning, there was very little difference between the 40-percent and 60-percent stocking treatments. After 5 years, oak stems <1.1 ft were greater in stands thinned to 60 percent stocking, but number of stems in the 1.1 to 5.0 and over 5 ft height classes were about the same for each stocking treatment (table 3). Stands thinned to 40 percent stocking produced significantly more ash and cherry stems in the 1.1 to 5.0 and over 5 ft height classes than stands thinned to 60 percent.

While the number of oak, ash, and cherry reproduction increased following thinning, the actual number of stems is small when compared to the increase in competing stems of other species. Stems of other species taller than 1 ft increased from about 8,000 per acre before thinning to 12,000 to 15,000 per acre in 5 years. Stands thinned to 40-percent stocking produced significantly more large competing stems of other species (table 3).

Effects of Understory Control.--Understory control significantly increased the number of oak stems in the 1.1 to 5.0 and over 5 ft height classes, but there was no difference between the complete control and partial control treatments (table 3). Ash and cherry reproduction did not respond to understory control. Although there was a slight increase in the number of stems over 5 ft in height with the complete and partial control treatments, differences between the control and noncontrol treatments were not significant.

Effects of understory control on competing stems, after 5 years, is only apparent in the numbers of large stems. The number of large competing stems decreased significantly with increasing intensity of understory control (table 3).

New Reproduction.--Establishment of new reproduction after treatment was erratic and varied greatly among stands and plots within stands. Although some new oak seedlings were inventoried during each remeasurement, most of the new reproduction for northern red and black oaks resulted from the 1980 acorn crop. Five-year oak seedling establishment ranged from 200 to 6,000 per acre and averaged 1,250 seedlings per acre. The amount of new oak reproduction was not related to site index, overstory density, or understory control treatments.

Table 3.--Reproduction 5 years after treatment as affected by site index, residual stocking, and understory treatment

Species and height	Pretreatment	Site index (feet) 60	Site index (feet) 75	Residual stocking (percent) 40	Residual stocking (percent) 60	Understory treatment 1[1]	Understory treatment 2	Understory treatment 3
----feet----				number of stems				
Oaks[2]								
<1.1	1601	1642a[3]	2273a	1630a	2385b	2000a	2094a	1778a
1.1-5.0	115	378a	446a	349b	475a	529b	500b	208a
>5.0	0	41a	26a	44a	28a	46b	50b	12a
Ash and cherry								
<1.1	691	513a	413a	463a	463a	424a	407a	560a
1.1-5.0	400	866a	644a	900b	614a	738a	705a	822a
>5.0	5	279a	147a	271b	155a	247a	242a	150a
Other species								
<1.1	4577	3163a	2717a	2413a	3470a	2940a	2884a	3000a
1.1-5.0	6286	9411a	9966a	10024a	9352a	8290a	10990a	9784a
>5.0	1488	3991a	3420a	4450b	2961a	1533a	3828b	5755c

1/1 = All stems treated; 2 = Stems >5 ft treated; 3 = No treatment.
2/White, black, and northern red oaks.
3/Site index, stocking, or understory treatment means in rows followed by the same letter are not significantly different at the 0.05 level.

New ash and cherry reproduction was much lower than oak, averaging about 340 seedlings per acre, and was not influenced by site quality or thinning treatments.

Mortality.--Mortality of advance oak, ash, and cherry reproduction occurred throughout the 5-year period following treatment, but the greatest losses were associated with the severe drought of 1980. More than half the small oak stems (<1.1 ft) and 20 percent of the large oak reproduction died in the 5 years following treatment. About two-thirds of the mortality occurred during the first year. Mortality for new oak reproduction averaged only about 5 percent. First-year mortality for small oak reproduction was greatest under stands thinned to 40-percent stocking, but there were no differences in mortality levels between stocking treatments for the 5-year period. Understory control did not influence mortality of oak reproduction.

Losses of ash and cherry reproduction were much lower than for the oaks. About 20 percent of the small ash and cherry reproduction and only 8 percent of the large stems died after treatment. All of the new ash and cherry reproduction survived. Mortality of the ash and cherry reproduction was not influenced by the overstory or understory treatments.

Height Growth After Treatment

Oak, ash, and cherry seedlings established after treatments produced the greatest height growth in stands with all competing stems removed (table 4). Seedlings in stands thinned to 40 percent stocking were also slightly taller and had larger stem diameters than seedlings in stands at 60-percent stocking, but the differences were not significant.

Table 4.--Total height of new oak, ash, and cherry seedling reproduction established after treatment

Stocking treatment	Understory treatment 1[1]	Understory treatment 2	Understory treatment 3
	feet		
Oaks[2]			
40-percent stocking	0.85c[3]	0.74b	0.55a
60-percent stocking	0.78b	0.58a	0.53a
Ash and cherry			
40-percent stocking	1.11b	0.83a	0.70a
60-percent stocking	0.97b	0.76a	0.70a

1/1 = All stems treated; 2 = Stems >5 ft treated; 3 = No treatment.
2/White, black, and northern red oaks.
3/Means in rows followed by the same letter are not significantly different at the 0.05 level.

Net height growth of oak advance reproduction established prior to treatment was relatively small, but varied significantly with initial size, overstory density and intensity of understory control (table 5). Small oak reproduction (<1.1 ft) grew best in stands thinned to 40- or 60-percent stocking where all competing understory stems had been removed, but the increase in height averaged only about 0.5 ft in 5 years. Larger oak reproduction responded to overstory density and intensity of understory

Table 5.--Net 5-year height growth of pretreatment oak, ash, and cherry reproduction

Stocking treatment	Understory treatment: Stems <1.1 feet 1[1]	2	3	Stems >1.1 feet 1	2	3
	feet					
Oaks[2]						
40-percent stocking	0.55b[3]	0.27a	0.27a	1.33c	0.82b	0.63a*[4]
60-percent stocking	0.43b	0.25a	0.20a	1.05c	0.72b	0.26a
Ash and cherry						
40-percent stocking	2.45b	2.50b	1.73a*	3.57b	3.72b	3.04a*
60-percent stocking	1.73a	1.72a	1.73a	2.87a	2.60a	2.34a

1/1 = All stems treated; 2 = Stems >5 ft treated; 3 = No treatment.
2/White, black, and northern red oaks.
3/Stems <1.1 or stems >1.1 means in rows followed by the same letter are not significant at the 0.05 level.
4/* = Stocking treatment significant at 0.05 level.

control. Best height growth occurred in stands thinned to 40-percent stocking with complete understory control averaging 1.3 ft. Poorest growth, averaging 0.3 ft, was associated with overstory densities of 60 percent and no understory control.

Ash and cherry reproduction grew best in stands thinned to 40-percent stocking with either partial or complete control of competing understory stems (table 5). Height of small ash and cherry reproduction increased by about 2.5 ft while larger stems grew more than 3.5 ft over the 5-year period.

DISCUSSION

The primary objective in applying the shelterwood method in mature upland oak stands is to develop a sufficient amount of oak advance reproduction that can compete successfully following overstory removal. This may be accomplished through establishment and growth of new seedlings and/or enhanced development of small established stems. In this study, all overstory and understory density control treatments increased the average size of oak, ash, and cherry reproduction. The number of oak stems taller than 1 ft increased from about 100 per acre before treatment to more than 500 per acre in stands with partial or complete understory control. The number of ash and cherry stems taller than 1 ft increased by 400 to 800 per acre after thinning. Most of the increase resulted from smaller pretreatment stems and new reproduction growing into the 1.1- to 3.0-ft height classes (table 6). Most of the oak reproduction taller than 5 ft developed from stump sprouts, primarily in stands where the site index was 60 ft. Only about 20 stump sprouts per acre were observed in the stands where site index was 75 ft. Graney and Rogerson (1985) reported that stump sprouts would be a minor component of the oak regeneration on good Boston Mountain sites after harvest. Based on prethinning diameter distributions for oak growth and yield plots representing 70- and 80-year-old stands where site indexes were 70 and 80 ft, predicted stump sprouting (Sander and others 1984) for black, northern red, and white oaks would average fewer than 40 per acre. Therefore, development of small oak reproduction into the larger size classes will be required to maintain a significant oak component in future stands.

Ash and cherry reproduction taller than 5 ft developed from older seedlings and seedling sprouts. Ash and cherry stump sprouts, though few in number, averaged nearly 3 ft in height growth per year, and some stems exceeded heights of 20 ft after 5 years. Ash and cherry seedling sprouts and stump sprouts were the dominant reproduction in stands receiving understory control treatments.

Although overstory and understory treatments imposed in this study resulted in substantial increases in the number of oak, ash, and cherry stems taller than 1 ft, the average 5-year increase in height for established reproduction, particularly oaks, was relatively small. Small oak reproduction averaged only about 0.1 ft of height growth per year, while larger oak stems grew about 0.2 to 0.3 ft per year under thinned stands with little or no initial competition from understory stems. Ash and cherry heights increased by an average of 2.5 to 3.5 ft over the 5 years after treatments, with many stems exceeding 10 ft in total height.

The rather small 5-year net height increase observed for oak reproduction in this study may not be indicative of the possible long-term growth responses to the overstory and understory density control treatments. The severe drought of 1980 affected reproduction of all species, but the impact on the oaks was very pronounced. More than half the small oak reproduction was lost to mortality due to the drought, and most of the

Table 6.--Mean height distribution of reproduction stems per acre in stands prior to treatment and 5 years after understory treatment

Understory treatment	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/						
Pretreatment	1601	84	16	10	5	0
1 2/	2000	409	66	25	29	46
2	1865	395	51	15	39	50
3	1778	170	20	4	14	12
Ash and cherry						
Pretreatment	691	200	108	51	36	5
1	424	315	177	172	74	247
2	208	302	161	154	88	242
3	560	285	275	150	112	150
Other species						
Pretreatment	4577	2648	1435	1170	1033	1488
1	3493	3278	2296	1750	966	1533
2	2858	3822	2920	2462	1786	3828
3	2250	2940	2844	2392	1608	5755

1/White, black, and northern oaks.
2/1 = All stems treated; 2 = Stems >5 ft treated; 3 = No treatment.

surviving stems died back and resprouted during the first 3 years following treatment. Maximum height growth for oak reproduction occurred the fourth and fifth years after treatment. If this growth trend continues through the tenth growing season, stands receiving the complete understory control treatments should produce a significant increase in large oak stems taller than 5 ft.

Establishment of new oak, ash, and cherry reproduction after treatment was highly variable and was not affected by overstory or understory treatments. However, development of the new reproduction was strongly influenced by understory competition. In stands with all competing stems controlled, oak, ash, and cherry seedlings were significantly taller and had larger tops and signficantly larger stem diameters than seedlings in stands with partial or no understory control.

In stands thinned to 60-percent stocking, complete understory control treatment remained effective through the fifth year after treatment, with most oak, ash, and cherry reproduction either free-to-grow or subject to light-to-moderate competition. Although there was rapid development of competing understory between the second and fifth years, most are single stems and less than 5 ft tall. Ash and cherry are the only reproduction stems taller than 10 ft.

Understory control in stands thinned to 60-percent stocking should remain effective for an additional period of time as overstory canopies expand and slow the development of competing understory species. Mortality in residual stands due to the 1980 drought or other causes resulted in lower overstory densities than desired and could have contributed to the rapid development of competing understory stems in the stands thinned to 60-percent stocking.

Complete understory control in stands thinned to 40-percent stocking was effective through the fifth year, but most of the small oak reproduction will soon be overtopped by competing species. Under the relatively open conditions of the 40-percent treatment, development of the competing understory is rapid, and by the fifth year more than 4,000 stems per acre were taller than 5 ft. The competion problem under heavily thinned stands was compounded by a surge of herbaceous vegetation and vine development, especially in stands where the site index was 75 ft. In these stands, the slower growing oak reproduction will be affected more by the increased competition. Ash and cherry reproduction are growing as well or better than competing stems. Sassafras (Sassafras albidum (Nutt.) Nees) and black locust (Robinia pseudoacacia L.) were abundant after 5 years in stands where all nondesirable stems had been treated, although these species were rare or absent in pretreatment inventories. Pawpaw is also a major component in the understories on the better sites. The remainder of the new understories developing after treatment were mainly the same species that were present before treatment and developed from smaller seedlings or seedling sprouts from stems cut but not killed by the herbicide treatment. Multiple stem sprouts from stumps of larger cut stems were absent in every stand where all nondesirable stems had been treated.

The partial understory control treatment significantly increased growth of oak, ash, and cherry reproduction, but the effects of this treatment will probably not extend beyond the fifth year as residual understory stems continue to develop. Understory development is most pronounced under stands thinned to 40-percent stocking where all small oak stems and most of the larger stems are now overtopped by competing stems. Only ash and cherry have maintained a favorable competitive advantage in stands receiving the partial control treatment.

Growth of desirable reproduction was poorest in stands where understories were not treated. Height growth for most oak reproduction averaged less than 0.3 ft in 5 years. Only large oak stems in the heavily thinned stands grew more than 0.5 ft over the 5-year period. Ash and cherry reproduction grew slower under the noncontrol treatment, but still produced height increases of 2 to 3 feet, which was greater than oak reproduction growth for all overstory and understory treatments.

CONCLUSIONS

The shelterwood method, combined with adequate understory control, should be an effective system to enhance development of established desirable reproduction in upland oak stands in the Boston Mountains. The number of oak, ash, and cherry stems taller than 1 ft was significantly greater in thinned stands where competing understory stems were controlled with herbicides. Ash and cherry produced a greater response to overstory and understory treatments than the oaks. Although understory control produced the greatest growth response in stands thinned to 40-percent overstory stocking, development of competing understory stems will soon overtake the slower growing oak reproduction. Only ash and cherry will compete successfully with nondesirable understory stems. Maintaining an overstory density of 60 percent or more will result in slower growth of desirable reproduction but should discourage rapid redevelopment of competing understory stems.

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