Regeneration of Northern Hardwoods in the Northeast with the Shelterwood Method

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ABSTRACT. Study plots (¼ ac) were located in four northern hardwood stands in Vermont, and shelterwood canopy covers of 40, 60, 80, and 100%, and a control (no cutting) were established. Regeneration on small plots within the treated areas was sampled over a 3-year period and the composition of saplings determined after 6 years.

While there were substantial increases in amount of regeneration under most canopy covers, there was no significant differences due to treatment. Some important trends, however, were evident. Sugar maple showed some increase in seedling density under most canopy densities with up to 68,000 new sugar maple seedlings per acre under 60% canopy cover. Yellow birch did best under 40 to 80% canopy cover and with good soil scarification. White ash increased under most densities but was best at about 80% canopy cover. Competitors, beech, striped maple, and hobblebush, increased under most densities. At about 60% canopy cover and less, raspberries and blackberries, pin cherry, and other shade-intolerant species increase in abundance.

Among regeneration less than 3 ft tall after 3 years, preferred species outnumbered less preferred species by 5 to 1. Among regeneration over 3 ft tall when examined 6 years after treatment, the less preferred species, on average, outnumber preferred species by 2 to 1 (sugar maple 0–3430/ac, yellow birch 0–1920/ac, beech 200–2220/ac and striped maple 0–3130/ac).

Most beech regeneration seemed to arise as root suckers. Small striped maple grew rapidly and assumed dominance among the regeneration when released. Northern hardwoods have diverse composition in the overstory, and much of the regeneration tallied after 3 years was already in place when the shelterwood cuts were made. Advanced regeneration as well as new regeneration is the key to success, or failure, if it is predominantly undesirable species.

In implementing a shelterwood in northern hardwoods, 60 to 80% canopy cover seems good for most species. All trees below the main canopy should be cut to create a high canopy shade. Undesirable species should be controlled by cutting or possibly herbicides before or when the stand is cut, with additional treatment as necessary to maintain desired composition.

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The wide array of trees and shrubs that occur in northern hardwood stands of the northeastern United States display a considerable range in tolerance to shade and diverse modes of regeneration including seeding, root suckers, stump sprouting, and layering. This diversity presents considerable challenges to the silviculturist in regenerating the most preferred species in acceptable densities.

In the northern hardwood stands of the Northeast, the main canopy is usually dominated by American beech, sugar maple, yellow birch, and numerous associates of varying economic value. On former agricultural land red maple is often abundant. Depending to some degree on site, striped maple, mountain maple, and witch hobble may be common in the understory and survive under dense shade for considerable time. If the upper canopy is opened, these understory species readily increase height growth, crown spread, and crown density.

In addition to new regeneration that may occur after a cut, many of the more preferred timber species are advance-growth dependent. Unless advance growth seedlings have their root system well established in mineral soil enabling them to ensure the sun and wind exposure following a complete overstory removal, seedling mortality will likely be high. The shelterwood method of regeneration, involving retaining part of the original canopy as shelter, can be used to further this establishment process and also obtain new regeneration. This method is viewed as having good promise for regenerating many of our hardwood species.

Over the years the shelterwood method has been used to regenerate numerous hardwood and conifer species in the eastern United States and in many cases has proven successful. Hannah (1988) has reviewed much of the literature on the shelterwood method in the Northeast. On public lands in much of the Northeast the shelterwood method is gaining in favor for regeneration of northern hardwood and oak stands. The method is also being used on some industrial lands. On nonindustrial private forestlands, however, diameter limit and selective cutting are among the predominant harvesting methods.

Though the shelterwood method has been used with many species, the research base to support its use with northern hardwoods is limited. Godman and Tubbs (1973) studied its application with northern hardwoods in the Lake States, obtained good regeneration, and established silvicultural guidelines. The method was used in New York, coupled with beech control and deer management to regenerate hardwood stands to the most valued species. Kelty and Nyland (1981) found regeneration there satisfactory under two-cut shelterwoods with 40 to 50 ft^2 of overwood.

Because soil conditions and stand composition in Vermont differ from New York and the Lake States, a study of shelterwood application in the Green Mountains was initiated. In Vermont understory species like striped maple, witch hobble, hay-scented fern, and occasionally raspberry and blackberry, often present a serious challenge to obtaining desired regeneration. One aim of the study was to see how sugar maple, yellow birch, and white ash would succeed if some cleaning was done in the understory but competitors were not controlled with herbicides.

STUDY AREA AND METHODS

Four well-stocked, mature northern hardwood stands in the Green Mountain range were selected for study. Study sites are located in northern and central Vermont on the Mt. Mansfield, Camel's Hump, and Okemo state forests and on private land east of the main Green Mountain range in the town of Orange. All stands are on soils of sandy loam or silt loam texture derived from glacial till with a compacted subsoil at 18 to 30 in. below the surface that impedes downward water movement.

Within each stand two treatment blocks were established, one above the other along the contour. Within each block five treatments, implemented as percent crown cover (Godman and Tubbs 1973), were established, each on a ¼-ac-plot with a 66 ft border strip around it. Shelterwood treatments of

40% (BA 50–60), 60% (BA 70–80), 80% (BA 90–100), and 100% (BA 110–120) crown cover and a no-cut (control) treatment—estimated at 120–130% (BA 120–130) crown cover—were randomly assigned to these plots. Because of limited stand area at Orange, only the 40%, 80%, and control treatments were established.

All treatment areas had advanced growth present after the cut though it varied considerably in density and height. In all treatments except "control," the understory trees over 6 ft tall but below the main canopy layer were cut; the 100% canopy cover had only trees beneath the main canopy and over 6 ft tall removed. No cutting was done in the control areas. In other treatments some main canopy trees were removed to obtain the prescribed high crown cover. Desired species, and other valuable trees of good form and quality, were favored to remain as the seed source and shelterwood. Marked trees were harvested as part of regular timber sale activities. Plots were entered with a rubber tire skidder but multiple trip skid trails through the plots were kept minimal.

Regeneration within each treatment area was sampled on 16 circular plots each 10.8 ft^2 in area. Counts were made of the seedlings by species and recorded in three height classes: <9, 9–18, and 18 in. to 3 ft. Using the same plot center to establish a 2.5 milacre plot, saplings 3–6 ft tall, and 6 ft tall to 3.5 in. dbh were tallied by species. Seedling and sapling counts were made before harvest, and each year thereafter for three growing seasons. Plots for saplings were also measured in 1989 and 1990 to determine the dominant sapling species.

Many of the seedling regeneration plots had few or no trees in some of the three designated height classes. To simplify the statistical analysis the three height classes, seedlings up to 3 ft tall, were combined, and an average count of each species at each measurement period was determined for the 16 plots. Tests of significant differences were made for each of the six most common species (sugar maple, yellow birch, white ash, American beech, striped maple, witch hobble). The other species (red spruce, balsam fir, mountain maple, red maple, black cherry, pin cherry, white birch, mountain ash, elderberry) occurred too infrequently for analysis. Data for seedlings (<3 ft tall) and saplings (>3 ft tall to 3.5 in. dbh) were analyzed for five treatments common to three stands and for three treatments common to four stands.

Initial statistical analysis by Cochran's F-test indicated nonhomogeneous variance and nonnormal data. Data transforming was ineffective, thus the ANOVA-F-test, Kurskal-Wallis nonparametric Chi-square test, and the Student-Newman-Kuel (SNK) test of significance were used where appropriate.

RESULTS

In statistical testing of regeneration response in this study, the mean increase in seedling density by species for each treatment (average of 16 plots) after 3 years was used. In the analysis of five treatments common to three stands (Orange excluded), though there were substantial increases in seedling densities for most species × treatment combinations, there were no significant differences for any of the six species due to shelterwood density. There are, however, significant differences between stands; an SNK test indicates the Mt. Mansfield stand has significantly (P = 0.05) more sugar maple, yellow birch, and striped maple than the Okemo and Camels Hump stands.

In the analysis of regeneration increases among three shelterwood treatments (40%, 80%, control) common to all four stands there are no significant differences in amount of new regeneration due to density of canopy cover for each of the six principal species. The SNK test again indicates stand differences with significantly more (P = 0.05) new sugar maple seedlings under 3 ft tall in the Mt. Mansfield and Orange stands than in the Camels Hump and Okemo stands (Table 1). These stand differences in both cases may in part be due to differences in occurrence of good seed years among stands, seed tree density, and possibly microsite and environmental factors favoring establishment.

Among the four sites studied there was more sugar maple, yellow birch, and white ash under most canopy densities 3 years after the cut than there were before shelterwood cutting (Table 1). Sugar maple has the greatest increases, up to 82,000 more seedlings per acre under a crown cover of 80% (90–100 BA). Yellow birch was second in regeneration abundance, with up to 64,000 more seedlings per acre after 3 years. White ash increased by over

Table 1. Average change in seedling density (<3 ft tall) per acre resulting from five shelterwood treatments in four northern hardwood stands in Vermont, and totals of most preferred and less preferred seedlings in 1983 and 1985.

Stand	Percent canopy cover	Net 3-year change Most preferred species (seedlings/ac)			Total seedlings Fall '85	Total seedlings Spring '83	Net 3 year change Less preferred species (seedlings/ac)			Total seedlings Fall '85	Total seedlings Spring '83
		Sugar maple	Yellow birch	White ash			American beech	Striped maple	Witch hobble		
Mansfield	40	60,300	64,000	0	126,900	2,780	10,000	11,000	0	28,100	6,700
	60	68,000	21,500	253	111,700	22,100	880	4,800	1,650	15,600	8,200
	80	36,000	21,000	1,640	61,000	2,400	−600	5,900	1,130	22,250	12,650
	100	37,000	37,000	0	75,100	1,520	−1,400	3,300	2,800	20,350	15,550
	Control	53,500	−600	0	118,900	65,900	−600	100	0	5,570	6,070
Camels Hump	40	−6,000	16,000	4,680	61,200	46,500	−2,150	−2,400	0	2,150	6,700
	60	10,000	20,700	9,330	73,600	33,510	600	1,900	−2,150	8,600	8,800
	80	7,400	1,400	5,690	67,200	52,700	−900	−6,300	−5,000	3,670	15,800
	100	−19,000	−250	3,240	37,500	53,100	−2,000	−3,000	2,900	13,480	15,570
	Control	−3,000	0	1,390	19,350	21,100	2,530	3,670	4,170	16,400	6,070
Okemo	40	−8,220	−1,010	−1,310	7,400	17,950	5,940	−1,900	−1,010	9,980	6,960
	60	6,000	−500	−1,000	35,530	31,000	400	250	250	6,320	5,440
	80	11,700	−250	1,150	30,360	41,220	−1,500	−2,900	−2,020	2,780	4,450
	100	−5,100	−630	−250	51,100	57,160	500	−100	−260	5,830	5,640
	Control	11,000	−130	1,010	36,840	24,500	250	700	−1,390	8,220	8,600
Orange	40	18,800	1,010	0	60,500	40,700	1,500	1,000	0	7,480	6,470
	60	—	—	—	—	—	—	—	—	—	—
	80	82,200	0	0	150,220	56,660	−100	700	0	6,670	5,820
	100	—	—	—	—	—	—	—	—	—	—
	Control	95,000	0	0	129,600	34,640	−250	−50	−120	6,680	6,590

9,000 seedlings per acre in stands where there was an abundant seed source. Losses of regeneration also occurred. Sugar maple decreased by up to 19,000 seedlings per acre, and yellow birch and white ash by up to 1,300 seedlings per acre. Among less preferred new regeneration under 3 ft tall, striped maple was most abundant overall followed by beech and witch hobble. After 3 years, total density of preferred seedlings less than 3 ft tall of 150,000+ stems per acre, and less-preferred seedlings of 30,000+ stems per acre were found (Table 1).

Sugar maple was the predominant seed source on all sites and can apparently regenerate well under a wide range of canopy densities. There were considerably more new sugar maple seedlings at Mt. Mansfield and Orange than at Okemo and Camels Hump. Yellow birch regenerated best under canopy covers of 40 and 60% at Mansfield and Camels Hump where there were ample yellow birch seed trees in the overwood (Fig. 1). Birch seedlings are most abundant in scarified spots, about 5% of the area, and in skid trails. White ash regenerated best in the Camels Hump stand where there was an abundant seed source. Ash seedlings were lost in the Okemo stand despite an ample but low vigor seed source, possibly due to deer browsing.

Less preferred species showed substantial increases in seedling sized stems per acre: beech 10,000, striped maple 11,000, witch hobble 4,170 (Table 1). Some treatments also showed substantial decreases, the result of natural mortality as existing seedlings grew larger, logging damage, or other unknown factors. These less preferred species can often form a fairly continuous understory canopy or dense thickets and discourage establishment of desired regeneration (Fig. 2). Despite substantial increases of less preferred species 3 years after treatments they were still, on average, outnumbered by preferred seedlings by 5 to 1, a ratio that should seemingly assure adequate desirable regeneration. Some treatments did have fewer preferred and/or less preferred seedlings 3 years after shelterwood cutting.

Many new seedlings can potentially be added to the stand with the shelterwood method, but the regeneration outcome may depend more on the composition and growth of advanced regeneration after the cut is made. Data from the 2.5 milacre plots indicate that for most treatments there are substantial increases in the numbers of both preferred and the less preferred saplings over the 3 growing seasons; however, there are no significant differences due to shelterwood density (Table 2). Most of these saplings developed from seedlings present when the cuts were made, but some may have originated from fast growing seedlings established after the cuts. There were increases of up to 3,900 sugar maple saplings per acre, 350 yellow birch, but only 25 white ash per acre (Table 2). Increases among less preferred species ranged up to 1,280 beech, 1,770 striped maple, and 1,440 witch hobble (Table 2). Unlike among the seedling size class, there were no decreases in new sapling density over the 3-year period. In 1983 less preferred species over 3 ft tall outnumbered the preferred species by 3.5 to 1; in 1985 it was 2.5 to 1. In 1989 a resurvey of 4 plots in each treatment indicated a ratio of 2.3 to 1. Preferred species appear to be gaining but dominate on only 3 of the 18 two-plot averaged treatments (Table 3).

In 1990, plots were remeasured at Mt. Mansfield and Orange to determine percent stocking by a preferred sapling among the two dominant saplings on the 16 plots within each treatment. This survey indicated that at Mt. Mansfield among the 40% canopy cover plots, 69 to 75% had sugar maple, yellow birch, or white ash among the two dominants. In all other treatments beech or striped maple dominated on 62 to 87% of the plots. Among plots examined at Camels Hump one area had up to 50% stocking with at least one dominant preferred species. Maximum stocking at Orange with at least one preferred species dominant was 13% among all treatments. Limitations in the study design preclude rigorous testing of this measure of desirable stocking, but the high degree of variability observed in this survey suggests no significant differences in percent stocking due to shelterwood density.

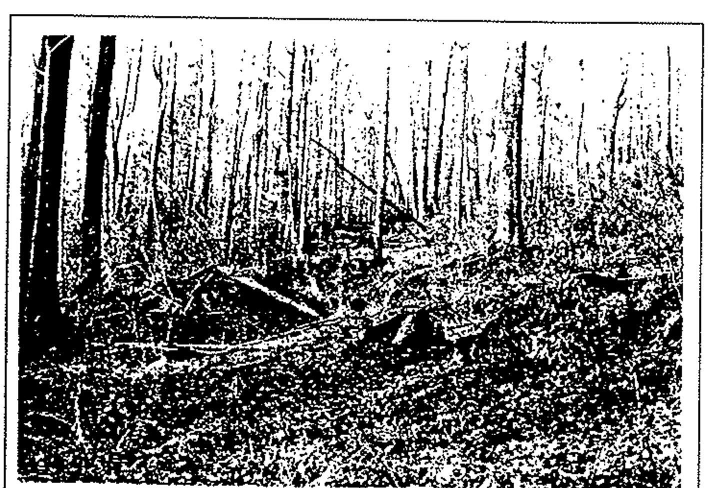

Fig. 1. Example of 40% canopy cover (foreground). Yellow birch is abundant in scarified areas while beech suckers have formed dense thickets in some locations.

DISCUSSION

Although there are no statistically significant differences in amount of new desirable regeneration due to the four different shelterwood density treatments tested in this study, there is ample new regeneration and some useful findings for applied silviculture. The four stands studied, though not highly diverse in composition of the main canopy, are considerably more diverse when the understory is considered.

Two hypothetical models serve to illustrate the conditions of simple and diverse stand composition and the challenges of obtaining regeneration in each. If a seed-producing stand of a single shade-tolerant species such as sugar maple exists and there is no other woody or nonwoody vegetation in the understory or within seeding distance, no viable stored seed, and ideal seedbed and shading conditions are created, then regeneration should be easy. In the Northeast, sugar bushes after decades of silvicultural cleaning approximate this model. As an example of this, a maple stand with a few scattered ash, initially part of this study, had a carpet of 6 in. tall maple seedlings when the shelterwood cut was made. After 7 years it now has a dense maple understory 5 ft high under 40 and 80% canopy cover with a few scattered ash. There are virtually no other competitive or less preferred species among the regeneration.

In contrast to the one species model, as more species are added to the stand with differing regeneration modes and requirements, the task of regeneration becomes more difficult. If there is no advanced regeneration in the stand, then the species that seeds in greatest abundance and grows fastest under a given condition is likely to dominate. If advanced regeneration is present and its growth requirements are compatible with the created canopy conditions, the most dominant and/or fast-

Fig. 2. An example of 80% canopy cover in a northern hardwood stand. Appearance of the understory is typical of many stands. Beech is abundant in this particular plot; witch hobble, striped maple and hay-scented fern are also strong competitors.

est growing will likely continue dominating. Presence of advance regeneration strongly influences composition of the next young stand following cutting. Growth habits, competitiveness, and cultural treatments shape the final stand.

In the four stands and three to five treatments examined in this study, there was, in most cases, abundant advanced regeneration when the shelterwood cuts were made, usually dominated by one or more of the six featured species. Given the range of shelterwood canopy densities in this study and cutting of all understory trees taller than 6 ft, sugar maple seedlings and saplings increased in density under most canopy conditions but seem to do best under 80% crown cover (90–100 BA). Even areas that had no cutting added sugar maple to the understory, but seedlings grew very slowly in height.

Among other preferred species, yellow birch seems to establish best under 60% (70–80 BA) crown cover. When cover is less than 60%, however, pin cherry and blackberries can become strong competitors. Advanced growth birch seedlings >3 ft high when the study began responded best in the shelterwood with 40% canopy cover (BA 50–60). Birch regeneration is best on a mineral seedbed. White ash was only found in any abundance in the Camels Hump and Okemo stands where there was a substantial seed source. Ash regeneration will likely be best under 60 to 80% crown cover. Most white ash seed usually germinates the second year after dispersal. Very few new black cherry, red spruce, or other commercially desirable species entered the stand.

Among the less preferred species beech is included because of its abundant root suckering potential, uncertainty about whether suckers will reach merchantable size and produce seed, disease susceptibility, and low commercial value. A beech component in stands is certainly acceptable; it adds diversity to the composition and has considerable wildlife value. If a beech seed source exists, regeneration should be accomplished with little difficulty either by seed or stable root suckers. Density of beech, quite abundant at the outset, increased in most stands and under most canopy treatments. It is suspected that suckers dominate in the stands sampled. In the stand at Orange one of the 40% canopy plots had much beech in the original overstory. Within 2 years after the cut, beech suckers were quite abundant and about 3 ft high. After 6 years, the sugar maple seedlings, present as small advance growth seedlings before the cut, were slowly making their way through these suckers. In this case, density of the beech may be limiting deer browse activity that is apparent on the advance growth maple in the 80% and control plots where beech was not as plentiful. Beech was one of the principal competitors in many of the treatments. An average increase of 690 stems in the sapling size class over 3 years indicates vigorous growth of seedlings and root suckers following release.

Table 2. Average change in sapling density (>3.3 ft tall to 3.5 in. dbh) per acre resulting from five shelterwood treatments in four northern hardwood stands in Vermont and totals of most preferred and less preferred saplings in 1983 and 1985.

Stand	Percent canopy cover	Net 3-year change Most preferred species (saplings/ac)			Total saplings Fall '85	Total saplings Spring '83	Net 3-year change Less preferred species (saplings/ac)			Total saplings Fall '85	Total saplings Spring '83
		Sugar maple	Yellow birch	White ash			American beech	Striped maple	Witch hobble		
Mt. Mansfield	40	61	315	0	375	580	210	635	25	870	950
State Forest	60	140	230	25	395	1,440	890	25	65	980	1,220
	80	155	12	12	180	150	980	886	12	1,878	1,550
	100	160	215	0	375	303	1,280	770	140	2,190	1,630
	Control	630	350	12	990	1,110	800	320	25	1,145	790
Camels Hump	40	80	12	0	92	36	110	65	150	325	211
State Forest	60	280	0	0	280	50	320	720	0	1,040	495
	80	200	70	0	270	50	720	215	110	1,045	645
	100	250	25	12	287	253	510	390	370	1,270	732
	Control	110	12	25	147	12	890	850	215	1,950	1,065
Okemo	40	24	53	0	77	280	340	770	0	1,100	2,600
State Forest	60	510	80	0	590	570	920	950	80	1,950	2,040
	80	510	12	36	560	525	1,090	820	12	1,920	3,315
	100	3,900	120	0	4,020	450	800	940	80	1,820	1,860
	Control	1,700	80	0	1,780	750	470	1,770	1,440	3,680	2,720
Orange	40	340	0	0	340	93	950	460	0	1,410	790
	60	—	—	—	—	—	—	—	—	—	—
	80	24	0	0	24	0	660	370	0	1,030	425
	100	—	—	—	—	—	—	—	—	—	—
	Control	100	24	12	136	50	480	240	0	670	460

Table 3. Sapling density per acre (trees 6 ft tall to 3.5 in. dbh) in four shelterwood stands in Vermont in 1989, six growing seasons after a shelterwood cut.

Stand	Percent canopy cover	Sugar maple	Yellow birch	American beech	Striped maple
Mt. Mansfield State Forest	40	101	1920	1165	960
	60	50	1010	2220	100
	80	101	455	1770	2025
	100	50	800	1515	1620
	Control	202	355	1060	405
Camel Hump State Forest	40	1520	1160	810	250
	60	760	202	1575	2270
	80	1470	150	1370	455
	100	404	200	555	760
	Control	0	0	2075	960
Okemo[a] State Forest	40	505	303	707	3130
	60	0	0	2120	0
	80	101	0	1010	1010
	100	3434	0	605	810
	Control	710	200	1210	1110
Orange	40	1420	51	355	355
	60	—	—	—	—
	80	50	0	1170	1430
	100	—	—	—	—
	Control	50	0	202	715

[a] Sample of four regeneration plots within each treatment area within one block.

Striped maple was present on all sites, but density increased the most at Mt. Mansfield where there is an abundant seed source, trees exceeding 6 in. dbh and up to 50 ft in height. The average increase into the sapling size class of over 600 stems per acre indicates that small advance growth seedlings respond well to shelterwood cutting and grow rapidly in height (Hibbs et al. 1980). This tree appears to have the potential for outgrowing sugar maple, ash, and birch under all amounts of canopy cover and can thus present serious competition to desired regeneration.

Witch hobble, though it seldom grows over 6 ft tall, can form dense thickets and heavy shade. In this study witch hobble was abundant on three sites, showed variable response on two sites, and increased stem density substantially at Mansfield. When witch hobble occurs in dense thickets there was little desirable regeneration. The observed decreases in witch hobble density are encouraging but not readily explainable; some of these stems have moved into the sapling size class, where they tend to branch out and create even more shade. Witch hobble clearly presents a problem for desired regeneration when it occurs in great abundance.

In this study there has been a substantial increase in number of new seedlings of all species in most treatments after 3 years, and among seedlings the preferred species dominate by 5 to 1. Many of these stems were advance growth seedlings and saplings when the study began. This advanced growth, when released by shelterwood cutting, will play a significant role in development of the next stand.

Six years after shelterwood cuts, the presence of more than two less preferred saplings for each preferred sapling is reason for concern. Most ¼ ac study plots are less than 50% stocked by preferred species in a dominant position. This suggests that a silvicultural cleaning among saplings should be made during the early years of stand development following shelterwood cuts. Application of a thorough cleaning before or at the time of the shelterwood cut should be considered to minimize problems. Tierson (1969) demonstrated effective control of beech with herbicides. Herbicide practices if accepted by the public are available to control most undesirable understory competitors and give the desired regeneration a chance (Horsley and Bjorkborn 1983, Horsley 1990). Hay-scented fern, another major competitor in many northern hardwood stands, and the allelopathic effects it has on desired regeneration, may also be controlled with herbicides (Horsley 1977). Hayscented fern was present in most treatments in this study but was not considered a major hindrance to regeneration except in localized areas.

CONCLUSIONS AND RECOMMENDATIONS

Based on trends in the data, and observations made in these and other stands, it appears that 60 to 80% canopy cover (ca. 70–100 BA) can provide suitable canopy conditions for sugar maple, white ash, and yellow birch regeneration. If the goal is yellow birch, then crown density should be nearer 60% (60–70 BA) with good scarification to expose a mineral soil seedbed. Canopy covers of less than 60% will tend to promote establishment of raspberries and blackberries, pin cherry, sedges, ferns, and other forbs.

To be successful with the shelterwood method it is important to evaluate the advanced regeneration and plan how to manage it. The most dominant advance regeneration capable of remaining in the main canopy is like to dominate in the next stand. If this vegetation is shade tolerant but not capable of remaining in dominant position, e.g., witch hobble and striped maple, it will no doubt hinder establishment of preferred species and delay final stand development. If less preferred species represent more than 50% of the advanced regeneration, steps should be taken to control density of this vegetation, preferably before the first cut of the shelterwood is made.

When planning a shelterwood, consider the following practices:

1. In cutting stands for shelterwood regeneration, remove trees from the lower canopy levels first to achieve the desired canopy density; the goal is to have a shelterwood provided by high shade (Godman and Tubbs 1973). Consider removing all overtopped trees unless they show potential as future crop trees.
2. Consider a cleaning before the first cut of the shelterwood (preparatory cut) is made, particularly if undesirables represent more than 50% of the advanced regeneration and dominate. Herbicide treatment of stumps can also be considered to reduce sprouting. If a three-cut shelterwood is used, another cleaning can be done to coincide with the second cut (seed cut). A third cleaning can be done, if necessary, when the overwood is removed.
3. Consider removing the overwood when the regeneration is 4 to 6 ft high. If a low density irregular shelterwood is desired for other management objectives, such as esthetics and wildlife, cleanings can be done as needed to maintain desired composition in the developing stand. Reinforcement planting can also be considered, preferably just after the first cut to increase species diversity.

The shelterwood method clearly has good potential for regenerating northern hardwood stands. To achieve the desired composition in the regeneration, one must not only create proper shelterwood conditions in the overstory but effectively manage the developing understory. A similar approach to stand treatment will likely be effective in other northeastern forest cover types as well. □

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Growth Response of Upland Oak Sawtimber Stands to Thinning in Connecticut[1]

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ABSTRACT. Thirty pairs of thinned and unthinned plots in roadside fuelwood areas, and 12 plots in each of 2 commercial cordwood thinnings were located in Connecticut oak sawtimber stands. Thinning during 1969–82 reduced stocking on plots an average of 30%. Subsequent stand basal area growth, cubic-foot growth, and board-foot growth were similar among all treatments. There was no decrease in stem quality nor increase in epicormic branching associated with thinning. Thinning mature oak sawtimber stands provides forest managers an opportunity to capture volume of declining trees while increasing growth on residual oak sawtimber.

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There are 24 million ac of oak-hickory sawtimber in the northern United States (Waddell et al. 1989). The high proportion of oak-hickory forest classified as sawtimber in the northeastern region, e.g., 67% in Connecticut, presents a challenge to forest managers wanting to create regulated forests. Harvest of mature timber would create a short-term glut, followed by a long-term shortfall, and pass the present unbalanced size structure to the next generation of foresters. Thinning would recover material from declining trees, but the response of mature oak sawtimber stands to thinning is not well understood. Current recommendations are to stop thinnings in oak stands at ages 60–70 on average sites in the central states (Sander 1977), and at age 95 in southern New England (Hibbs and Bentley 1983). There has been a paucity of reports which examine the response of mature oak sawtimber stands to thinning (Rudolph and Lemmien 1976, Sonderman 1984), especially in the Northeast.

In Connecticut an aggressive program of roadside fuelwood and commercial cordwood thinnings on state forests occurred during the 1970s and early 1980s in response to the increased demand for wood for home heating. An estimated 11,000 ac, 5.5% of forest managed by the Connecticut Department of Environment Protection, were thinned. State foresters relate that nearly all stands adjacent to passable roads were thinned at least once. This widespread cutting provided an opportunity to examine the effect of thinning on the growth and quality of oak sawtimber stands.

The objective of this study was to determine whether growth and quality of oak sawtimber stands were affected by roadside fuelwood and commercial cordwood thinning. Individual roadside fuelwood cuts were marked without formal plans and can best be described as a mixture of salvage and free-thinning with the removal of culls and poles. Commercial cordwood thinning had written cutting plans with the objective of increasing growth on residual sawtimber, especially oaks. Commercial plots were included to provide a comparison of thinning larger areas (>10 ac) using skidders with smaller scale thinning without heavy equipment.

METHODS

Study Areas

Paired plots were established on adjacent thinned and unthinned (control) areas at 30 roadside fuelwood sites located throughout Connecticut for a total of 60 plots. Sites were selected using the following criteria: red-black-scarlet oak in the upper canopy, roadside fuelwood thinning before 1983, no cutting or other disturbance

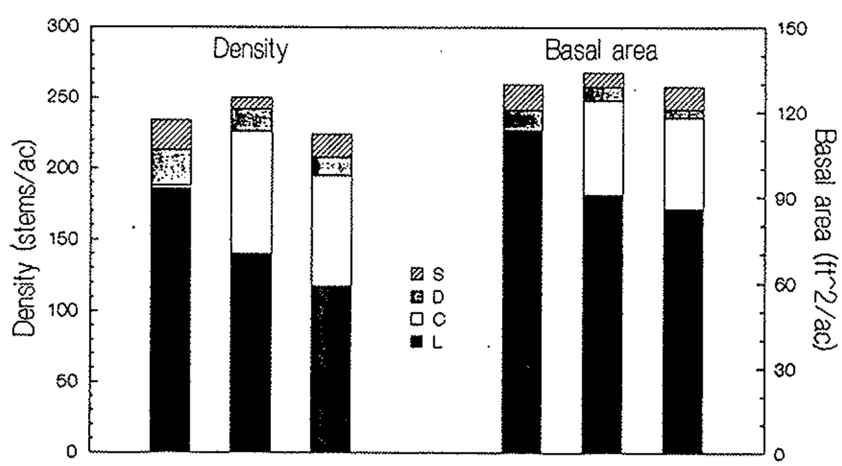

Fig. 1. The 1988 density (stems/ac) and basal area (ft²/ac) by thinning method of living stems (L), cut stems (C), dead and down stems (D), and snags (S).

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