United States
Department of
Agriculture

Forest Service

Northeastern Forest Experiment Station

Research Paper
NE-581

1986

Allegheny Hardwood Regeneration Response to Even-age Harvesting Methods

John C. Bjorkbom
Russell S. Walters

The Authors

John C. Bjorkbom was a research forester with the Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Warren, Pennsylvania. He retired in 1982.

Russell S. Walters is a research forester with the Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Warren, Pennsylvania. He has been engaged in research on the regeneration of Allegheny hardwoods since 1982.

Manuscript received for publication 4 September 1985

Abstract

Allegheny hardwood regeneration response to block clearcutting, alternate strip clearcutting, and two-cut shelterwood, and in an uncut control was compared. Stand regeneration success was evaluated 5 years after harvest. Clearcutting resulted in high mortality of advance regeneration. Thus, regeneration by block clearcutting was not successful, though both alternate strip clearcutting harvests were successful. The first cut of the shelterwood established new seedlings but did not stimulate growth. Regeneration level increased from inadequate to adequate and remained so after the final harvest. New seedlings appeared in the control after each seed crop, but few survived. Fenced seedlings grew taller in all harvest areas.

Contents

Study Area 1
  Regeneration 2
  Seed production 2
  Environmental factors 2
  Cutting methods 3
Analysis of Data 3
Results and Discussion 3
  Logging mortality 3
  Environmental factors 4
  Effect of seed source 5
  Initial regeneration differences 5
  Effect of treatment on the total number of stems 5
  Effect of treatment on regeneration stocking 7
  Effect of treatment on stem height 8
  Effect of fencing 9
  Old versus new seedlings 9
  Herbaceous covers 9
Summary and Conclusions 12
Literature cited 12

Cover photo—Fencing to prevent deer browsing allowed seedlings to grow taller. Also, regeneration stocking increased with a greater proportion of desirable species.

The Allegheny hardwood forest consists primarily of black cherry, red maple, sugar maple, and beech.[1] Associated species include white ash, yellow-poplar, sweet and yellow birch, cucumbertree, and hemlock. Many of these species demand light, and some form of even-age silviculture is essential for their regeneration. In the past, this usually meant block clearcutting.

Block clearcutting regenerates relatively large areas when advance regeneration of desired species is adequate. However, advance seedlings are too few or too small in more than two-thirds of all Allegheny hardwood stands (Marquis and Bjorkbom 1982). Clearcutting removes the seed source and provides a harsh environment for the germination and survival of seeds stored in the forest floor. Seed dispersal from adjacent areas is often inadequate. Thus in the absence of advance regeneration, other even-age silvicultural systems, such as shelterwood cutting or alternate strip clearcutting, may be more appropriate.

We studied the effects of these three cutting methods on the survival and growth of advance seedlings and on the establishment and growth of seedlings appearing after cutting. We observed solar radiation, soil moisture, and surface temperature of the forest floor. Also, we noted changes in herbaceous vegetation and determined the impact of deer browsing on tree reproduction by fencing some plots. Both the shelterwood and alternate strip clearcutting methods provided a less harsh environment and successfully regenerated the stands. Fencing in all treatments protected seedlings from browsing, resulting in taller seedlings.

Study Area

This study was on the Kane Experimental Forest in northwestern Pennsylvania. The site is on unglaciated, relatively uniform terrain of the Allegheny Plateau at an elevation of 1,900 feet.

The block clearcutting treatment occupied a 25.6-acre area (16.0 chains by 16.0 chains) on upper flat and midslope positions. Slope averaged 14 percent on a 255 degree aspect. The soils belong to the Hazelton (coarse loamy, mixed, mesic Typic Dystrochrepts) and Cookport (fine loamy, mixed, mesic Aquic Fragiudults) series. These soils, formed in place from the underlying bedrock, have loam to silt loam textures throughout their profiles and range from well to moderately well drained. Dormant season perched water tables occur only at depths exceeding 2 feet.

The shelterwood treatment area covered 6.4 acres (8.0 chains by 8.0 chains) on upper flat and midslope positions. Slope was 13 percent and aspect 194 degrees. The soils here are very similar to those found in the block clearcut.

[1]Scientific names of species referred to in this report are listed at the end of this paper.

The alternate strip clearcutting area totaled 3.2 acres among four adjacent strips, each 1.0 chain wide and 8.0 chains long. The strips were oriented in a Northwest-Southeast direction in the upper flat position with a 6 percent slope and a 246 degree aspect. Soils in this treatment are loams and silt loams and belong almost exclusively to the Cookport series. They range from moderately well to somewhat poorly drained. Mottling is quite variable. The dormant season water table occurs at depths between 6 and 24 inches. They are slightly wetter than the soils in the other plots.

An uncut control area of 6.4 acres (8.0 chains by 8.0 chains) on the upper flat had a 9 percent slope and 134 degree aspect. Soil textures are principally loams and silt loams, rarely sandy loam. Mottling was not observed in the first 2 feet of the soil. Soils in this treatment are generally similar to those in the block clearcut and shelterwood treatment plots.

All areas supported fully stocked stands of Allegheny hardwoods ranging in relative stand density from 98 to 104 percent. However, species compositions were not similar and total basal area amounts differed by as much as 35 square feet (Table 1). The basal area of the block clearcut stand totaled 44 square feet per acre with 44 percent in red maple, 27 percent in beech, and only 9 percent in black cherry. In the alternate strip clearcutting area, the total basal area per acre of 162 square feet was principally black cherry (40 percent) with equal amounts (22 percent) of red maple and sugar maple. The total basal area in the shelterwood area was 153 square feet per acre with 52 percent in red maple and 29 percent divided about equally between black cherry and beech. In the uncut control stand, four species—beech, birch, red maple, and sugar maple—accounted for 81 percent of the total basal area (127 square feet). The proportions among those species were roughly similar, ranging from 23 percent beech to 17 percent sugar maple. Black cherry accounted for only 7 percent.

Advance regeneration varied considerably among the treatment areas. Black cherry regeneration was particularly abundant in the alternate strip clearcutting area, which also had the greatest amount of black cherry in the overstory. Red maple seedlings were most abundant in the strip clearcut and shelterwood. Beech was generally quite evenly distributed. Other principal species present were sugar maple and hemlock (Table 1).

Logging to create the block clearcutting, strip clearcutting, and shelterwood treatments began in November 1973 and was completed in January 1974. Subsequently, the shelterwood residual stand and the alternate, previously uncut, strips were then clearcut during May and June 1979. To determine the regeneration and environmental effects of these cutting methods, we observed and measured the advance regeneration, the regeneration that developed after cutting, seed production, soil moisture, surface temperature of the forest floor, solar radiation, herbaceous vegetation, and browsing by deer.

Table 1.—Selected pretreatment characteristics of the overstory (1972) and the regeneration (Spring 1973) by treatment

Characteristic	Block clearcut	Alternate strip clearcut	Shelterwood	Control
Area, acres	25.6	3.2	6.4	6.4
Relative stand density (percent)	104	100	100	98
Median stand diameter[1]	12.7	13.9	13.3	11.0
Basal area/acre (ft²)				
Black cherry	13	64	23	9
Sugar maple	9	36	14	22
Red maple	64	36	80	26
Birch	7	2	4	26
Beech	39	14	21	29
Hemlock	8	10	10	<1
Other	4	0	1	15
Total	144	162	153	127
Regeneration:				
Percent stocking	21	84	48	8
Stems/acre (× 1000)				
Black cherry	7.5	141.0	17.6	1.8
Red maple	7.9	21.0	22.5	2.4
Beech	3.6	2.8	2.4	2.4
Other	0.5	1.8	0.2	4.9
Total	19.5	166.6	42.7	11.5

[1]Diameter at the midpoint of the stand basal area.

Regeneration

For estimating the amount of regeneration, we established a pair of 6-foot-radius plots at each of 24 randomly located sampling points in the block clearcut area, at 20 sampling points in each of the shelterwood and control areas, and at 10 sample points in each of the four alternate cut strips. To evaluate the impact of browsing by deer, one plot in each pair was fenced.

A 1.25-chain-wide isolation area surrounding the regeneration sampling area minimized the influence of the adjacent uncut stand on seedling establishment and development in the block clearcutting and shelterwood treatments. However, in the alternate strip clearcutting area, we did not leave an isolation area around the regeneration sampling plots because the shading and seed source effects of adjacent uncut areas are essential attributes of strip clearcutting.

Regeneration inventories were made for each area in the spring of 1973, and at the end of each growing season from 1973 through 1976, and again in 1978. In addition, the regeneration in the shelterwood, alternate strip, and control areas was also inventoried in 1984. Seedlings were recorded by species and by height class as less than 1 foot, 1 to 3 feet, 3 to 5 feet, and greater than 5 feet. To aid in interpreting the effects of treatment, the species occurring in this study were further classified as desirable, commercial, and noncommercial. Desirable species include black cherry, sugar maple, red maple, cucumbertree, and yellow-poplar. Commercial species include beech, birch (yellow and sweet), and hemlock in addition to the desirable species. Noncommercial species are principally pin cherry and striped maple, but also include serviceberry and eastern hophornbeam.

Based on these inventory data, the 6-foot-radius regeneration plots were classed as stocked or not stocked. To be stocked before the final harvest, a plot must contain at least 25 black cherry stems or 100 stems of all desirable species taller than 2 inches. Two to five years after the final harvest, both total number of stems per plot and number of stems taller than 3 feet were considered in determining whether a plot was stocked. Thus, stocking after cutting was calculated as the average of the proportion of plots with at least five stems taller than 3 feet and the proportion of plots with at least 25 stems total. Either before or after the final harvest, regeneration in a stand is considered adequate if at least 70 percent of the sample plots meet these criteria (Marquis and Bjorkbom 1982).

The seedlings present in 1972, and those originating in 1973, 1974, and 1975, were marked each year with a different color. Seedlings becoming established after 1975 were not marked. Thus, it was possible in 1978 to identify those advance seedlings that were at least 2 years old at the time of cutting, those 1 year old at the time of cutting, and the new seedlings that originated during the first, second, and later years after cutting.

Seed Production

Four randomly located seed traps in each treatment area were used to estimate seed production. Each trap was 0.25 milacre in area (3.3 by 3.3 feet). Seed collections were made at the end of the seed dispersal periods during 1973 through 1976.

Environmental Factors

Soil moisture was measured with a nuclear surface moisture gauge at weekly intervals throughout the growing season from 1973 through 1976. These measurements were made at eight randomly selected points in each treatment.

Surface temperatures of the forest floor were measured with an infrared field thermometer. These measurements were made at 20 randomly selected points in each treatment area (24 in the block clearcutting) at weekly intervals during the growing seasons of 1975 and 1976.

Solar radiation was estimated using an anthracene-benzene chemical light meter (Marquis and Yelenosky 1962). These estimates were made at 20 randomly selected points in each treatment area (24 in the block clearcutting) for a 1-week period during the 1973 and 1976 growing season.

Cutting Methods

The block clearcutting was done as a final harvest cutting method to release advance regeneration present on the site and to stimulate germination of seed lying dormant in the forest floor. The treatment consisted of cutting all trees in the 2-inch and larger diameter classes. However, only 21 percent of the regeneration plots in this stand were stocked before treatment (Table 1). Thus, this stand did not meet the established guideline of at least 70 percent stocking for adequate regeneration (Marquis and Bjorkbom 1982).

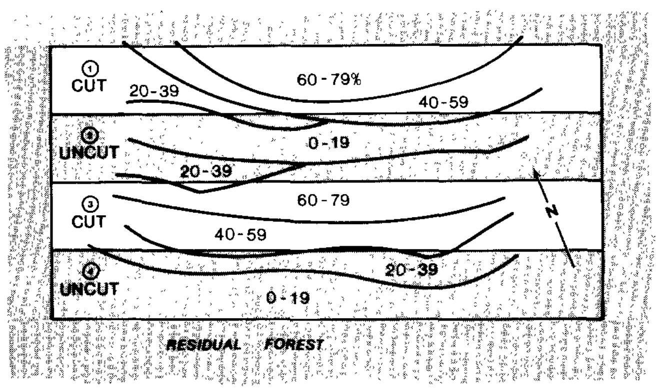

Figure 1.—Percentage of full sunlight at various locations within the alternate strip cutting treatment. August 3 to 13, 1976.

The strip clearcutting was also a final harvest and removed all trees in the 2-inch and larger diameter classes. This treatment differed in that four adjacent 1-chain-wide strips were established but only strips 1 and 3 were cut, leaving the alternate strips 2 and 4 uncut. All cutting and skidding activities were confined within the area cut so as not to disturb the adjacent uncut strips. In this treatment, the narrow clearcuts (1 chain wide) received some shade and possibly seed from the adjacent uncut areas. Conversely, the uncut strips adjacent to the cutting received additional light from the sides thus favoring seedling establishment and growth (Fig. 1). The uncut strips were subsequently cut 5 years later in 1979. All four strips had adequate advance regeneration before cutting with 84 percent stocked plots (Table 1).

When the block clearcut and the clearcut strips were harvested, the shelterwood area received the preparatory harvest, the first of two planned cuts. The objective of the preparatory harvest was to open the stand and thus stimulate seed production on residual trees and increase light reaching the forest floor to favor seedling establishment and development. Advance regeneration was to increase in size and numbers before the final harvest due in 5 years. The first cut removed about 26 percent of the total basal area in trees 4 inches and larger leaving a stand of 69 percent relative density. The larger and best quality stems of desired species at a uniform spacing were retained.

Analysis of Data

Statistical significance in all tests in this study was accepted at the 0.05 level.

Differences in sunlight, soil moisture, and soil temperature were tested by analysis of variance. Percentage data were transformed by arcsine. Differences among individual treatments were compared using Fisher's protected LSD.

The number of stems by species and size class were compared between fenced and unfenced plots within each treatment by a t-test for paired plots. This test was also used for comparing the number of stems by species (fenced and unfenced) in each treatment at the start of the study in 1973 with the number present in 1978.

Because the number of stems by species before cutting was so variable among plots, analysis of covariance was used to test treatment effects on number of stems by height class. The independent variable was the total number of stems in the fall of 1973, and the dependent variable was the number of stems by height class in the fall of 1978. Comparisons among the adjusted means were made using the Bonferroni t statistic (Bailey 1977).

Pin cherry was not present in any treatment area in 1973, therefore, analysis of variance was used to test treatment effects on the number of stems of this species by height class. Treatment means were compared using Fisher's protected LSD.

Results and Discussion

Logging Mortality

Logging generally destroys some advance regeneration. The greatest losses occur when the ground is bare of snow.

Losses are least with a deep snow cover. During the period of logging, snow depth measured 4 inches or less 83 percent of the time (U.S. Dep. Commer. 1973a, b; 1974a)—insufficient to afford much protection.

Seedling mortality due to logging was assumed as the difference between the before and after inventories of regeneration adjusted for the natural overwinter mortality (40 percent) that occurred in the uncut stands. Much of this natural mortality occurred among the numerous red maple germinants that appeared in 1973 but failed to survive in the dense shade of the uncut stands. Natural overwinter mortality of all species in the cut areas also may have been affected by the change in environmental factors resulting from cutting.

The highest logging mortality rate occurred in the block clearcut area (45 percent). The shelterwood plot had the least mortality—11 percent, and the cut strips were intermediate—19 percent of the advance regeneration. High mortality in the block clearcut resulted mostly from the extensive skidding needed to remove the large volume of timber cut, and because of the harsh environment created by the complete exposure of the site. Although the entire overstory was removed in the cut strips as well, mortality was less because the skidding was confined to one trail. Also, the shading effect of the adjacent uncut strips moderated soil and air temperatures, and soil moisture was inherently higher. The shelterwood received only a light partial cut and, although skidding was extensive, continuous use of the same skid trails did not occur. In addition, the residual overstory provided a favorable environment for survival.

Environmental Factors

Solar radiation levels and surface soil temperatures did not differ significantly among the individual treatment areas before cutting. Soil moisture was relatively uniform among the several areas; however, the level in the alternate strip cutting area was somewhat greater than that in the others. After logging, these factors differed substantially among the treatments. Knowing these differences helps to understand and explain the regeneration response to the various treatments.

Solar radiation. Prior to cutting, only about 5 percent of full sunlight filtered through the canopy to ground level—usually considered too little light for adequate seedling growth and only marginal for survival of all but the most tolerant species.

Cutting increased average light levels in the shelterwood and uncut strip treatments. The uncut strip (No. 2) bordered on both the north and south sides by cut strips received an average of 28 percent full sunlight, and the uncut strip bordered only on the north by a cut strip received an average of 13 percent (Fig. 1). The seed cut of the shelterwood treatment increased the light level there to 21 percent. The increased light levels in both the uncut strips and in the shelterwood were expected to result in better survival of advance seedlings and minor stimulation of height growth.

Light levels in the block clearcut and cut strips increased dramatically to 50 to 100 percent of full sunlight. Although these light levels should be near optimum for growth of the intolerant species, they also could produce high surface temperatures and surface moisture stress and thus reduce seedling establishment and survival. The cut strips—especially the south edges—receive partial shade that moderated both temperature and moisture stress (Fig. 1).

Surface temperature. Weekly growing season measurements of the forest floor surface temperature after treatment showed higher temperatures in the block clearcut than in the other treatment areas. However, temperatures in the block clearcut and the cut strips were not significantly different from one another, whereas, differences between the block clearcut and each of the other treatments were significant. Temperatures in the cut strips were often significantly higher than in the shelterwood, the uncut strips, and in the control. Temperatures among the latter three treatments rarely differed significantly (Table 2).

Table 2.—Average surface temperature and range in degrees Celsius by treatment and growing season[1]

Treatment	1975		1976	
	Average	Range[2]	Average	Range
Block clearcut	37c	16–60	37c	13–60
Alternate strip clearcut				
Originally cleared	26cd	9–60	28cd	14–60
Alternate	21d	10–60	24d	13–60
Shelterwood	22d	10–56	25d	13–54
Control	16d	4–31	21d	13–34

[1]Values in the same column followed by the same letter are not significantly different.

[2]Temperatures above 60°C exceeded the maximum limit of the infrared thermometer and were recorded as 60°C.

Surface temperatures of 50 to 54°C (122 to 130°F) often kill young seedlings (Salisbury and Ross 1969). In 1975, soil surface temperatures equalled or exceeded these levels on 8 measurement days from late May to the middle of August and probably killed some seedlings. Usually this occurred at only a few sampling points in any one treatment area but, by the end of July, lethal temperatures had occurred at all sampling points in the block clearcut. This pattern of surface temperatures occurred again in 1976.

Soil moisture. Soil moisture was significantly greater in the cut and uncut strips than in any other treatment in each year of measurement from 1973 through 1976 (Table 3). However, the differences were due to site rather than treatment. The strips occupied an almost level site with some inadequately drained areas where mottling occurred at

Table 3.—Average percentage of soil moisture by treatment and growing season

Treatment	1973	1974	1975	1976
Block clearcut	32b[1]	36b	35b	40b
Alternate strip clearcut				
Originally cleared	34a	45a	44a	46a
Alternate	35a	45a	44a	46a
Shelterwood	30c	37b	38b	40b
Control	31bc	37b	37b	41b

[1]Values in the same column followed by the same letter are not significantly different.

depths of 6 to 24 inches. The other treatment areas were on an inherently drier southwesterly slope with an average depth of mottling in excess of 24 inches.

Soil moisture, as measured by a neutron surface probe used in this study, applies to a relatively large volume of soil. Such measurements do not estimate accurately the soil moisture levels in those crucial areas immediately surrounding either seeds or the rootlets of new germinants. Soil moisture in those micro-environments may have reached critical levels and were not detected. The high surface temperatures experienced in the study areas (Table 2) suggest that evaporation could have contributed to soil moisture reaching critical levels.

Trends in percent moisture by volume for the alternate strips that had the highest moisture content and for the block clearcut that generally had the lowest moisture content are illustrated in Figure 2 for 1973 and 1974. Soil moisture in the

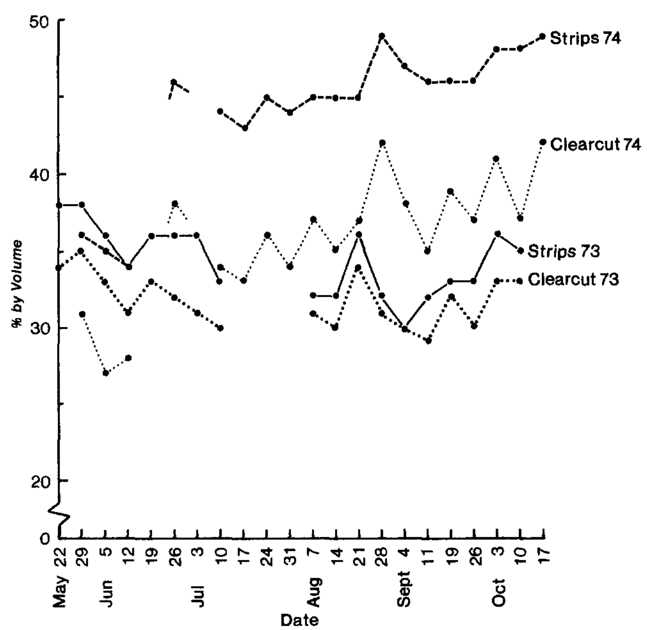

Figure 2.—Trends in percentage of soil moisture in the alternate strip clearcutting and block clearcut areas, 1973 and 1974.

shelterwood area in the control area was not significantly different than that in the block clearcut. Year of measurement seems to have had a greater effect on soil moisture than did treatment. The lowest soil moisture occurred in 1973 when the precipitation from May through October was about 2.4 inches below normal (U.S. Dep. Commer. 1973c); in 1974, the precipitation was about 4.4 inches above normal (U.S. Dep. Commer. 1974b).

Effect of Seed Source

Only in the first year after cutting did new seedlings become established in the block clearcut. These originated from seeds stored in the humus. Thereafter, seed sources were not available and few new seedlings appeared. New germinants appeared in the other treatment areas after each seed year.

Seed traps were maintained in all of the treatment areas from 1973 to 1976, but sizable seed crops occurred only in 1974 and 1975. Most of the collected seeds were red maple (86 percent) and black cherry (7 percent). Red maple seeds were trapped in all treatments though the block clearcutting received only a token number. Black cherry seeds were trapped in all areas except the block clearcut. Seeds of other species dispersed only in small amounts. Because the sample was so small and the amount of trapped seed varied so greatly within each treatment area, differences between areas could not be detected.

Initial regeneration differences

Before treatment, regeneration varied widely in the number of seedlings and in regeneration stocking (Table 1). The alternate strip clearcutting area averaged about 141,000 black cherry stems per acre, many more than in any other treatment. Apparently this abundance occurred because of the large number of seed-producing black cherry and relatively high soil moisture of the site. Although far fewer red maple seedlings were present, they outnumbered those found in the block clearcut and the control areas. The shelterwood area contained more black cherry and red maple seedlings and had a higher regeneration stocking than did either the block clearcut or the control area. These latter treatment areas were very low in numbers of seedlings and percent regeneration stocking.

The pretreatment stocking level of commercial species regeneration observed in the alternate strip, block clearcut, shelterwood, and control areas was 84, 21, 48, and 8 percent, respectively (Table 1). Only in the alternate strip area was stocking greater than the recommended minimum adequate level of 70 percent (Marquis and Bjorkbom 1982). Therefore, this was the only stand suitable for final harvest cutting in 1973.

Effect of treatment on the total number of stems

The total number of stems changed constantly in each treatment area during this study (Table 4). An obvious and expected change occurred the year after logging. The logging itself killed many seedlings. Many others could not survive in the harsh conditions in the cut-over stand. At the

Table 4.—Thousands of stems per acre by species and treatment in Spring 1973, 1974, 1978, and 1984

Species	Year	Block clearcut	Originally cleared strips	Alternate strips	Shelter-wood	Control
Black cherry	1973	7.5	99.0	182.6	17.6	1.8
	1974	.7	49.1	115.2	10.2	1.8
	1978	.9	32.8	137.4	22.2	1.4
	1984	—	—	15.2	7.3	.8
Red maple	1973	7.9	20.4	21.6	22.5	2.4
	1974	4.4	25.6	58.4	51.0	12.2
	1978	1.3	25.2	68.1	96.2	26.6
	1984	—	—	17.0	20.9	3.0
Beech	1973	3.6	2.9	2.7	2.4	2.4
	1974	35.8	10.2	2.7	7.2	3.2
	1978	12.0	2.7	3.7	4.4	4.2
	1984	—	—	2.9	4.0	4.9
Birch	1973	0	0	.1	0	0
	1974	5.4	5.4	1.4	7.8	0
	1978	1.2	3.8	1.6	2.0	0
	1984	—	—	4.4	1.0	0
Pin cherry	1973	0	0	0	0	0
	1974	42.9	3.0	.7	21.2	0
	1978	10.4	1.7	.1	.4	0
	1984	—	—	.3	.6	0
Other	1973	.5	2.7	1.1	.2	4.9
	1974	2.8	1.7	1.1	.5	9.0
	1978	.8	.8	3.4	1.4	5.4
	1984	—	—	1.4	.4	1.5
Total, all species	1973	19.5	125.0	208.1	42.7	11.5
	1974	92.0	95.0	179.5	97.9	26.2
	1978	26.6	67.0	214.3	125.6	37.6
	1984	—	—	41.2	34.3	10.2

same time, because of seedbed disturbance and increased light on the forest floor, newly dispersed seeds as well as viable seeds that had lain dormant in the humus germinated and beech root suckers developed. After the initial surge of new regeneration, changes continued but at a reduced level. Some seedlings died each year as they were crowded out by larger stems. Meanwhile, some new seedlings also appeared after each seed crop, though few of these survived more than 1 year.

Between 1973 and 1978, the number of stems in the cut strips were reduced by almost one-half. Large losses of black cherry during logging were not offset by the development of new stems that occurred elsewhere.

In the same period, regeneration increased by about one-third in the block clearcut. The increase was almost entirely beech root suckers and pin cherry seedlings that appeared the year after cutting. There were significantly more stems of these two species in this treatment than in any other. The pin cherry no doubt are from dormant seed in the floor of the undisturbed forest (Marquis 1975). Many of these germinate in response to the disturbance of heavy cutting. The triggering mechanism of this response may have been the elevated level of soluble nitrogen available in the soil after clearcutting (Auchmoody 1979). Increase in surface temperature after clearcutting, as we observed in this plot, accelerates the rate of organic nitrogen mineralization in forest soils (Theodoru and Bowen 1983).

The total number of seedlings increased slightly during the period 1973 to 1978 in the uncut alternate strips. New red maple germinants accounted for much of the increase. Because no cutting took place, few beech root suckers, birch, or pin cherry became established. By 1984, 5 years after these strips were cut, the total number per acre had decreased greatly with very large reductions in the number of black cherry and red maple seedlings.

In the shelterwood area, the total number of stems increased nearly threefold from 1973 to 1978. Red maple stems accounted for much of the increase as there were significantly more stems of this species here than in any other treatment. Although the number of black cherry stems decreased slightly after the preparatory cut, new cherry regeneration also became established. By 1978, this area contained significantly more black cherry stems than the block clearcut. The partial cutting did not stimulate much beech root suckering. A few birch and pin cherry germinated after the cutting, but not many survived. The number of stems present in 1984 reflect losses due to the logging of the overstory removal and the subsequent losses to increased competition as some stems increased in size.

Although the number of stems nearly tripled in the uncut control area between 1973 and 1978, the number present in 1978 was still much less than that in all other areas except the block clearcut. Red maple seedlings accounted for most of the increase with much smaller increases of black cherry and beech. No birch or pin cherry became established. By 1984, the total number of seedlings in this plot had declined by 1,300 seedlings below the 1973 level, with a 56 percent decrease in black cherry stems and increases of 104 percent in beech stems and 25 percent in red maple stems.

Effect of treatment on regeneration stocking

Between 1973 and 1978, regeneration stocking decreased in the block clearcut and strip final harvest cuttings and increased in the shelterwood and uncut preparatory cuttings. The stocking level of the uncut control area increased during the period 1973 to 1978, but then decreased greatly by 1984 (Table 5). This latter area contained a large number of small, newly germinated red maple seedlings in 1978 that did not survive till 1984.

The block clearcut area did not contain adequate stocking of regeneration before cutting in 1973, and by 1978, 5 years after cutting, it was even lower. This treatment did not successfully regenerate the stand. Stocking also decreased in the clearcut strips but, because of their high initial stocking, they remained satisfactorily stocked. In both these harvest cuts, stocking in 1978 was higher on fenced than unfenced plots.

The percentage of stocked regeneration plots in the shelterwood area increased from an unsatisfactory pretreatment level to a satisfactory level 5 years after the preparatory cut. In 1984, 5 years after the final harvest, stocking was adequate in both the fenced and unfenced plots. However, stocking in the unfenced plots is adequate only if all commercial species are considered, whereas the fenced plots are adequately stocked with desirable species and 100 percent stocked with commercial species. In the alternate uncut strips, initial stocking was high and increased somewhat by 1978. Five years after clearcutting, these strips were still adequately stocked. Fenced plots contained more desirable species than did the unfenced.

Table 5.—Stocking of regeneration by species group and treatment, 1973, 1978, and 1984, in percent

Species group and treatment	Before[1] treatment, 1973	After treatment, 1978		After treatment, 1984	
		Fenced	Unfenced	Fenced	Unfenced
Desirable Species					
Harvest cut:					
Block clearcut	21	13[2]	4[2]	—	—
Originally cleared strips	92	80[2]	62[2]	—	—
Preparatory cut:					
Shelterwood	48	75	90	90[2]	50[2]
Alternate strips	75	85	95	90[2]	80[2]
Control	8	35	35	0	0
Commercial Species					
Harvest cut:					
Block clearcut	21	58[2]	50[2]	—	—
Originally cleared strips	95	95[2]	75[2]	—	—
Preparatory cut:					
Shelterwood	48	85	95	100[2]	70[2]
Alternate strips	78	90	95	95[2]	88[2]
Control	8	40	40	0	0

[1]All plots unfenced at this time.

[2]Five years after final harvest cut. Based on the post cutting criteria; average proportion of plots with at least 25 stems total and 5 stems taller than 3 feet. All others based on precutting criteria; percent of plots with 25 black cherry stems or a total of 100 advance seedlings. Stocking of at least 70 percent is adequate.

Effect of treatment on stem height

Only harvest cuttings stimulated a sizable proportion of the regeneration to more than 1 foot in height in the 5 years after cutting (Table 6). The preparatory cuttings stimulated seedling height growth little in this period. Initially, the most seedling growth occurred on the fenced plots of the block clearcut where they received full sunlight and continuous protection from deer browsing. More than 80 percent of these stems were taller than 1 foot, and more than one-third grew to 5 feet or more. However, a large proportion of these taller seedlings were noncommercial pin cherry. The proportion of taller regeneration was less in the clearcut strips because of the partial shading effect of the adjacent uncut stands. In these strips, about two-thirds of the stems were over 1 foot tall and 1 in 10 was over 5 feet. In 1984, 5 years after final removal, both the alternate strip and shelterwood plots had more than 75 percent of stems taller than 1 foot, and very few of these were noncommercial species. On the unfenced plots in all treatments, the proportion of stems in the taller height classes was much less.

Table 6.—Percentage of commercial and noncommercial stems by treatment and height class, 1978 and 1984.

Height class (feet)	1978					1984[1]		
	Block clearcut	Clearcut strips	Alternate strips[2]	Shelter-wood[2]	Control	Alternate strips	Shelter-wood	Control
COMMERCIAL SPECIES								
Fenced plots:								
<1	17	34	82	91	94	23	17	78
1-3	23	38	15	6	4	19	37	14
3-5	8	14	1	1	<1	15	16	5
>5	4	6	1	<1	<1	37	25	3
Total	52	92	99	98	99	94	95	100
Unfenced plots:								
<1	37	69	91	97	94	54	28	63
1-3	27	26	7	1	4	26	57	25
3-5	4	3	<1	1	2	10	7	8
>5	1	1	<1	<1	<1	9	7	4
Total	69	99	99	99	100	99	99	100
NONCOMMERCIAL SPECIES								
Fenced plots:								
<1	1	<1	1	1	1	1	0	0
1-3	5	0	<1	<1	0	1	1	0
3-5	10	<1	<1	<1	0	1	1	0
>5	32	7	0	0	0	3	3	0
Total	48	8	1	2	1	6	5	0
Unfenced plots:								
<1	8	1	1	1	<1	<1	1	0
1-3	14	<1	<1	0	0	1	<1	0
3-5	5	<1	<1	0	0	0	0	0
>5	4	0	0	0	0	0	0	0
Total	31	1	1	1	<1	1	1	0

[1]Five years after the final overstory removal from the alternate strips and the shelterwood plots.
[2]Preparatory cutting treatments.

In terms of stems greater than 3 feet and 5 feet—criteria of successful regeneration after harvesting—treatment differences were evident 5 years after final harvest. There were significantly larger numbers of stems in these height classes in all species categories, but only in the fenced plots within these treatments. The number of desirable and commercial species in these height classes was favored by those treatments that provide some partial shade before final harvest, the shelterwood and the alternate strips. Tall noncommercial species, mostly pin cherry, developed in each of the harvest cuts with the most in the block clearcut. The number of stems by species, height class, and treatment on fenced and unfenced plots is given in Table 7.

Effect of fencing

Fencing had little effect on the total number of stems during the course of this study (Table 7). The only significant difference between fenced and unfenced plots in total stem number after harvest occurred in the clearcut strip treatment in 1978. The unfenced plots had more than twice as many seedlings as the fenced. These unfenced plots contained very large amounts of black cherry and red maple less than 1 foot tall. In a similar manner, the number of seedlings less than 1 foot tall was significantly greater in the unfenced than in the fenced plots in each harvest treatment. Conversely, the fenced plots in each harvest treatment contained a significantly greater number of taller seedlings than did the unfenced. When protected from browsing, seedlings grow taller and occupy more space crowding out smaller stems, whereas browsed seedlings remain small allowing room for larger numbers.

Regeneration stocking 5 years after final harvest was dramatically higher on the plots protected from deer browsing by fences (Table 5). With the exception of the block clearcut, all harvest cuts contained adequate stocking in desirable species when fenced, and stocking was even higher when all commercial species were included. Although these same treatments resulted in adequate stocking without fencing, the proportion of stocked plots was less and the species composition less desirable. The post-harvest stocking of the block clearcut was inadequate, even with the benefit of fencing. This suggests that deer browsing is not the only factor affecting regeneration. Stocking before cutting was low, logging destroyed much of the advance regeneration, and adequate new regeneration could not survive in the harsh environment created by complete removal of the overstory.

In the preparatory cuttings—the shelterwood and the uncut strips—and in the uncut control where less than optimum light was available, the effect of fencing was much less pronounced. Relatively few seedlings in these areas were taller than 1 foot and rarely did any exceed 3 feet (Table 6). It is possible that the seedlings outside the fences in these areas receiving low light levels were not browsed heavily because the deer were attracted to the nearby clearcuts. Clearcutting results in a flush of new vegetation providing much food. Both the block clearcut and the clearcut strip areas had a large number of new pin cherry (Table 4) and *Rubus* (Table 11) germinants; both of which are favored deer browse. This could have the effect of reducing browse pressure on the uncut and partial cut areas, helping to explain the lack of height difference inside and outside the fences. Also, browsing tends to be limited on small and slow-growing stems. Rapidly elongating seedlings are much more succulent and attractive to deer. In fact, this is partially the idea behind using shelterwood cutting in high-deer-density areas. The preparatory cut encourages the establishment of new seedlings while maintaining slow growth to avoid browsing until the number of seedlings is large enough to overwhelm the deer.

Old versus new seedlings

The old seedlings referred to here are those advance seedlings present in 1973 before cutting. In even-age harvest methods, advance regeneration stems are necessary for successful regeneration. Most of these old seedlings were black cherry, red maple, and beech. The new seedlings are those that became established in 1974 and later.

The number of old seedlings decreased over the study period with the greatest decreases occurring immediately after logging. Survival of these seedlings was lowest in the final harvest cuttings where the effects of logging were greatest and in the uncut control where the low light levels made survival difficult (Table 8).

Despite the mortality of the old seedlings and the establishment of new seedlings, the old seedlings represented a substantial proportion of the total regeneration in 1978 (Table 9). In addition, these seedlings, with their initial height advantage and already well-developed root systems, outgrew the new seedlings. In 1978, a greater proportion of the old seedlings was found in the taller height classes (Table 10).

Herbaceous covers

Hayscented fern, New York fern, short husk grass, and sedge occurred in all treatment areas in 1973, but the percentage of area covered was not great enough to be a regeneration problem (Marquis et al. 1975). Since these species can have an inhibitory effect on regeneration of black cherry and other desirable Allegheny hardwoods (Horsley 1977, Horsley and Marquis 1983), it is important to determine if the cutting methods used in this study may influence the spread of these ferns and grasses.

Prior to logging in 1973, a light fairly uniform fern cover grew throughout the treatment area. This coverage ranged from 8 percent in the block clearcut to 12 percent on the cut strips. By 1978, fern coverage had expanded on all plots except the block clearcut. The largest increase occurred in the shelterwood plot where the percentage of area covered nearly doubled to 20 percent. However, this is still not great enough to be considered an inhibitory problem for regeneration. The reasons for the fern coverage increase are not entirely clear, but considering the site requirements of ferns can be helpful. Both fern species commonly grow in moist, shady places (Fernald 1950). Thus, the least favorable location would be the hot, dry block clearcut and this treatment area did contain the least amount of fern cover. Conversely, the partial shade from the cut strips and shelterwood treatments is quite favorable. Also, as stated earlier, the cut strip area was moister than the others.

Table 7.—Thousands of stems per acre, by height class, species, and treatment on fenced (F) and unfenced (UF) plots, 5 years after harvest cutting

Species	Height class (feet)	Block clearcut F	Block clearcut UF	Clearcut strips F	Clearcut strips UF	Control F	Control UF	Shelterwood F	Shelterwood UF	Alternate strips F	Alternate strips UF	Control F	Control UF
Black cherry	<1	0.1	0.2	5.6 *	21.6	1.9	0.9	1.4	1.4	1.6 *	3.3	1.1 *	0.3
	1-3	.3	.5	11.0	19.5	.1	0	3.8	4.4	2.1 *	6.3	.2	0
	3-5	.3	.1	3.7	2.2	0	0	1.2	.7	2.4	4.4	0	0
	>5	.2	.1	1.4	.5	0	0	1.6 *	.2	6.5 *	3.8	0	0
	Total	0.9	0.9	21.8 *	43.8	2.0	0.9	8.0	6.7	12.6	17.8	1.3 *	0.3
Red maple	<1	0.6	0.9	7.8 *	36.7	26.6	26.7	4.3 *	6.8	4.0 *	17.9	3.7	2.1
	1-3	.6	.5	3.4 *	1.3	0	0	8.0	13.8	2.4	4.4	.1	0
	3-5	0	0	.9 *	0	0	0	3.9 *	1.0	1.6 *	.4	0	0
	>5	0	0	.3 *	0	0	0	4.0 *	0	3.3 *	.1	0	0
	Total	1.2	1.4	12.3 *	38.0	26.6	26.7	20.2	21.6	11.3 *	22.8	3.8	2.1
All desirables[1]	<1	0.9	1.5	13.5 *	58.4	34.5	31.6	5.7	8.2	5.5 *	21.2	6.7	3.4
	1-3	1.4	1.1	14.5	20.8	.1	0	11.8	18.2	4.5 *	10.7	.3	0
	3-5	.6 *	.1	4.9 *	2.2	0	0	5.1 *	1.7	4.1	4.8	0	0
	>5	.3 *	.1	1.8	.5	0	0	5.8 *	.2	9.8 *	3.9	0	0
	Total	3.2 *	2.8	34.7 *	81.9	34.6	31.6	28.4	28.3	23.9 *	40.6	7.0 *	3.4
Beech	<1	3.3 *	7.7	0.1	0.5	1.8	2.5	0.2	0.8	0.3	0.8	2.3	2.3
	1-3	4.5	5.4	1.2	.8	1.6	1.5	1.0	1.1	.4 *	1.7	1.2 *	2.2
	3-5	1.5 *	.9	.8	.8	.3	.5	.5	.6	.3	.5	.6	.7
	>5	.6 *	.2	.6	.6	.2	.1	1.9	2.0	1.3	.6	.3	.4
	Total	9.9	14.1	2.7	2.7	3.9	4.6	3.6	4.4	2.3	3.6	4.4	5.6
Other commercial[2]	<1	3.4 *	8.6	0.8 *	4.9	1.8	2.6	0.2	1.2	1.4	6.6	2.3	2.2
	1-3	4.6	6.3	1.7	2.4	1.6	1.5	1.2	1.2	1.4	3.0	1.3 *	2.2
	3-5	1.5 *	1.0	1.1 *	.8	.3	.5	.7	.5	.4	.6	.6	.7
	>5	.7 *	.2	.9	.6	.2	.1	3.0	2.0	1.6	.6	.3	.4
	Total	10.2 *	16.1	4.5 *	8.7	3.9	4.7	5.1	4.9	4.8	10.8	4.5	5.5
Desirable and commercial[1,2]	<1	4.3 *	10.1	14.3 *	63.3	36.3	34.2	5.9 *	9.4	6.9 *	27.8	9.0 *	5.6
	1-3	6.0	7.4	16.2	23.2	1.7	1.5	13.0	19.4	5.9 *	13.7	1.6	2.2
	3-5	2.1 *	1.1	6.0 *	3.0	.3	.5	5.8 *	2.2	4.5	5.4	.6	.7
	>5	1.0 *	.3	2.7	1.1	.2	.1	8.8 *	2.2	11.4 *	4.5	.3	.4
	Total	13.4 *	18.9	39.2 *	90.6	38.5	36.3	33.5	33.2	28.7 *	51.4	11.5	8.9
Noncommercial[3]	<1	0.2	2.3	0.2 *	0.5	0.1	0.1	0	0.2	0.2	0.1	0	0
	1-3	1.4 *	3.9	0 *	.2	0	0	.3	.1	.3	.6	0	0
	3-5	2.5 *	1.3	.2 *	0	0	0	.1	0	.2	0	0	0
	>5	8.3 *	1.0	2.8 *	0	0	0	1.1 *	0	1.1 *	0	0	0
	Total	12.4	8.5	3.2 *	0.7	0.1	0.1	1.5 *	0.3	1.8 *	0.7	0	0
All species	<1	4.5 *	12.4	14.5 *	63.8	36.4	34.3	5.9 *	9.6	7.1 *	27.9	9.0 *	5.6
	1-3	7.4 *	11.3	16.2	23.4	1.7	1.5	13.3	19.5	6.2 *	14.3	1.6	2.2
	3-5	4.6 *	2.4	6.2 *	3.0	.3	.5	5.9 *	2.2	4.7	5.4	.6	.7
	>5	9.3 *	1.3	5.5 *	1.1	.2	.1	9.9 *	2.2	12.5 *	4.5	.3	.4
	Total	25.8	27.4	42.4 *	91.3	38.6	36.4	35.0	33.5	30.5	52.1	11.5	8.9

* = Significant difference (0.05) between fenced (F) and unfenced (UF).
[1]Black cherry, red maple, sugar maple, white ash, yellow-poplar, and cucumbertree.
[2]Beech, sweet birch, yellow birch, and hemlock.
[3]Pin cherry, eastern hophornbeam, striped maple, and serviceberry.

Table 8.—Survival of old seedlings[1] by species and cutting method, 1978, *in percent*

Treatment	Black cherry	Red maple	Beech	All species
Block clearcut	3	1	24	3
Alternate strip clearcut				
Originally cleared strip	27	8	42	19
Alternate strip	38	24	81	34
Shelterwood	35	12	50	16
Control	26	9	65	17

[1]Seedlings present at the start of the study.

Table 9.—Old seedlings[1] as a percentage of total regeneration by species and cutting method, 1978

Treatment	Black cherry	Red maple	Beech	All species
Block clearcut	19	24	8	6
Alternate strip clearcut				
Originally cleared strip	68	20	44	43
Alternate strip	52	29	60	45
Shelterwood	19	10	31	12
Control	33	6	44	13

[1]Seedlings present at the start of the study.

Table 10.—Percentage of old[1] and new seedlings by height class, all treatments and species combined, 1978

Height class (feet)	Old Seedlings	New Seedlings	Total
<1	28	72	100
1-3	75	25	100
3-5	65	35	100
>5	71	29	100
	—	—	—
Total	37	63	100

[1]Seedlings present at the start of the study.

Grasses, primarily short husk grass and sedge, covered 3 percent or less of each treatment area in 1973 and, at this low level, did not present a regeneration problem. However, logging disturbance and increased light apparently stimulated the germination of seeds stored in the humus, and grass covers expanded. By 1978, 20 percent of the area in the cut strips was grass-covered—more than in any other treatment. Modest increases occurred in the other areas as well, except in the uncut control which did not change. Thus, grass coverage did increase in response to the cutting but not enough in any treatment area to become a regeneration problem.

Rubus differs from fern and grass in that its presence can be beneficial to regeneration. Numerous *Rubus* seeds germinate after cutting or other disturbance. The seedlings grow rapidly and often dominate a regeneration area for several years. Although it forms a dense canopy, the environment beneath is favorable for seed germination and seedling establishment of tree species. At the same time, it may provide new seedlings some short-term protection from browsing. Not only does the dense *Rubus* cover hide tree seedlings from the deer, but it is also highly desirable browse and the deer eat it instead of the tree seedlings. Further, *Rubus* may interfere with fern and grass (Horsley and Marquis 1983).

The establishment and growth of *Rubus,* not present in any treatment area in 1973, was affected by treatment and—because it was browsed heavily—by fencing. In 1978, the greatest amounts were found in the block clearcut and the cut strips with lesser amounts in the shelterwood and uncut strips. There was no *Rubus* in the uncut control. *Rubus* coverage in the unfenced plots was only a fraction of the amount present on the fenced plots, except in the block clearcut, where dense accumulations of slash may have protected the *Rubus* from browsing. Estimated *Rubus* coverage by treatment and fencing is shown in Table 11.

Other herbaceous plants such as adder's tongue, wood sorrel, violet, partridgeberry, and mosses were also present. The percentage of area covered by these plants was small and changed only slightly between 1973 and 1978.

Table 11.—Percentage of area covered by *Rubus* spp. by treatment, fenced and unfenced plots, 1978[1]

Treatment	Fenced plots	Unfenced plots
Block clearcut	58a	51a
Alternate strip clearcut		
Originally cleared	71a	16b
Alternate strip	25b	7c
Shelterwood	15b	2d
Control	0c	0d

[1]Values in the same column followed by the same letter are not significantly different.

Summary and Conclusions

The results of this study indicate that:

1. Cutting methods such as shelterwood or alternate strip clearcutting provide a moderate environment and avoid the extremes of light and temperature found in a block clearcut. The moderating influences of these methods where the complete overstory is removed in two stages improve establishment and survival but did not stimulate height growth of small seedlings prior to final harvest.

2. Cutting methods influence the amount of new regeneration of seedling origin. After cutting and germination of the cherry seed stored in the humus, no new black cherry seedlings appeared in the block clearcut treatment or the original cleared strips of the alternate strip clearcut treatment. In the shelterwood treatment and in the uncut strips of the alternate strip clearcut harvest treatment, a seed source remained and new black cherry seedlings continued to appear.

   Few maple or birch seedlings became established in the block clearcut because the seed dispersal distance from the surrounding stand was too great to obtain adequate seed distribution. But these seedlings appeared in all other treatments including the originally cleared strips where seed dispersal distance was not too great.

   Pin cherry seed stored in the humus germinated in response to higher light levels and/or increased soluble nitrogen concentration in the soil after cutting. The greatest number of seedlings became established in the block clearcut.

3. Advance regeneration is critical in the block clearcutting method because harvesting removes the seed trees, leaving only those seeds stored in the humus to help regenerate the area. Seeds of other species dispersed into the clearcut were inadequate for successful regeneration.

4. The number of seedlings present at the start of the study decreased during the study. However, advance regeneration accounted for a high proportion of the regeneration greater than 1 foot in height 5 years after harvest.

5. Stands with inadequate advance regeneration (<70 percent stocking) should not be clearcut; rather a treatment that removes only a portion of the overstory such as shelterwood should be used.

6. The new beech regeneration was principally of sprout origin and occurred almost exclusively in areas logged.

7. Fencing to prevent deer browsing allowed seedlings to grow taller as well as allowing regeneration stocking to increase with a greater proportion of desirable species. In particular, fencing made a major difference in regeneration stocking in the block clearcut, whereas regeneration in unfenced areas was nearly a total failure.

8. *Rubus* coverage increased greatly after cutting and the heavier the cutting the more *Rubus*. Fern and grass covers were also more extensive after treatment, though field observations suggest that these covers increased in moist rather than in dry sites within any treatment area. Caution should be used in areas where grass and/or fern coverage exceeds 30 percent.

Literature Cited

Auchmoody, L.R. **Nitrogen fertilization stimulates germination of dormant pin cherry seed.** Canadian Journal of Forest Research. 9:514–516; 1979.

Bailey, J.R. **Tables of the Bonferroni t statistic.** Journal of American Statistical Association. 72(358):369–378; 1977.

Fernald, Merritt Lyndon. **Grey's manual of botany.** 8th ed. New York: American Book Co.; 1950. 1632 p.

Horsley, Stephen B. **Allelopathic inhibition of black cherry. II.** Inhibition by woodland grass, ferns, and club moss. Canadian Journal of Forest Research. 7:515–519; 1977.

Horsley, Stephen B.; Marquis, David A. **Interference by weed and deer with Allegheny hardwood reproduction.** Canadian Journal of Forest Research. 13:61–69; 1983.

Marquis, David A. **Seed storage and germination under northern hardwood forests.** Canadian Journal of Forest Research. 5:478–484; 1975.

Marquis, David A.; Bjorkbom, John C. **Guidelines for evaluating regeneration before and after clearcutting Allegheny hardwoods.** Res. Note NE-307. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1982. 4 p.

Marquis, David A.; Yelenosky, George. **A chemical light meter for forest research.** Stn. Pap. No. 165. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1962. 25 p.

Marquis, David A.; Grisez, Ted J.; Bjorkbom, John C.; Roach, Benjamin A. **Interim guide to regeneration of Allegheny hardwoods.** Gen. Tech. Rep. NE-19. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1975. 14 p.

Salisbury, Frank B.; Ross, Cleon. **Plant physiology.** Belmont, CA: Wadsworth Publishing Co., Inc.; 1969. 747 p.

Theodoru, C.; Bowen, G.D. **Effects of temperature, moisture, and litter on nitrogen mineralization in *Pinus radiata* forest soils.** Australian Forest Research. 13:113–119; 1983.

U.S. Department of Commerce. **Climatological data.** Pennsylvania. Vol. 78, No. 11. Asheville, NC: U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service, 1973a.

U.S. Department of Commerce. **Climatological data.** Pennsylvania. Vol. 78, No. 12. Asheville, NC: U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service, 1973b.

U.S. Department of Commerce. **Climatological data.** Pennsylvania. Vol. 78, No. 13. Asheville, NC: U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service, 1973c.

U.S. Department of Commerce. **Climatological data.** Pennsylvania. Vol. 79, No. 1. Asheville, NC: U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service, 1974a.

U.S. Department of Commerce. **Climatological data.** Pennsylvania. Vol. 79, No. 13. Asheville, NC: U.S. Department of Commerce, National Oceanic & Atmospheric Administration, Environmental Data Service, 1974b.

COMMON AND SCIENTIFIC NAMES OF TREES AND PLANTS REFERRED TO IN THIS REPORT

Trees:

Ash, white	*Fraxinus americana* L.
Beech	*Fagus grandifolia* Ehrh.
Birch, sweet	*Betula lenta* L.
Birch, yellow	*Betula alleghaniensis* Britton
Cherry, black	*Prunus serotina* Ehrh.
Cherry, pin	*Prunus pensylvanica* L.f.
Cucumbertree	*Magnolia acuminata* L.
Eastern hophornbeam	*Ostrya virginiana* (Mill.) K. Koch
Hemlock	*Tsuga canadensis* (L.) Carr.
Maple, red	*Acer rubrum* L.
Maple, striped	*Acer pensylvanicum* L.
Maple, sugar	*Acer saccharum* Marsh.
Serviceberry	*Amelanchier arborea* (Michx. f.) Fern.
Yellow-poplar	*Liriodendron tulipifera* L.

Herbaceous plants:

Adder's tongue	*Erythronium americanum* Ker.
Fern, hayscented	*Dennstaedtia punctiloba* Michx.
Fern, New York	*Thelypteris noveboracensis* L.
Grass, short husk	*Brachyelytrum erectum* Schreb.
Mosses	*Lycopodium* spp.
Partridgeberry	*Mitchella repens* L.
Rubus (raspberry, blackberry)	*Rubus* spp.
Sedge	*Carex* spp.
Sorrel, wood	*Oxalis montana* Raf.
Violet	*Viola* spp.

Bjorkbom, John C.; Walters, Russell S. **Allegheny hardwood regeneration response to even-age harvesting methods.** Res. Pap. NE-581. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 13 p.

Allegheny hardwood regeneration response to block clearcutting, alternate strip clearcutting, and two-cut shelterwood, and in an uncut control was compared. Stand regeneration success was evaluated 5 years after harvest. Clearcutting resulted in high mortality of advance regeneration. Thus, regeneration by block clearcutting was not successful, though both alternate strip clearcutting harvests were successful. The first cut of the shelterwood established new seedlings but did not stimulate growth. Regeneration level increased from inadequate to adequate and remained so after the final harvest. New seedlings appeared in the control after each seed crop, but few survived. Fenced seedlings grew taller in all harvest areas.

ODC 221.21:221.22:221.1

Keywords: 2-cut shelterwood cutting, alternate strip clearcutting, block clearcutting

☆U.S. GOVERNMENT PRINTING OFFICE: 1986—605—026/40001

Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.