# SURVIVAL AND GROWTH OF PLANTED RED OAK AND WHITE ASH AS AFFECTED BY RESIDUAL OVERSTORY DENSITY, STOCK SIZE, AND DEER BROWSING

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Abstract.--Underplanting seedlings can be used to regenerate areas that lack natural regeneration. In south-central Pennsylvania, large and small northern red oak and white ash seedlings that were protected or left unprotected from deer were planted under 100, 60, and 30 percent residual overstory density. After 7 years, survival was 58 percent for protected red oak seedlings and 85 percent for protected white ash. For unprotected seedlings, survival was 13 percent for red oak and 28 percent for white ash. The height of protected seedlings was 1.1m (3.6 ft) for red oak and 1.8m (5.8 ft) for white ash. The height was 0.24m (0.8 ft) for unprotected red oak seedlings and 0.4m (1.3 ft) for unprotected white ash.

Stock size had no effect on survival of either species and only a small effect on height. Residual overstory density had a significant effect on survival and height of both species. The 100 percent density treatment had lower survival and less height growth than the 60 and 30 percent treatments. Interference from natural woody vegetation was heaviest in the 30 percent treatment.

Keywords: Underplanting, deer browsing, shelterwood cutting, *Quercus rubra* L., *Fraxinus americana* L.

## INTRODUCTION

Recent research on natural oak regeneration in Pennsylvania has shown that there is an almost complete absence of advance seedlings under many oak stands due mainly to inadequate numbers of viable acorns. The destruction of acorns by insects and consumption of the remaining seed by rodents, turkeys, and deer reduce the amount of viable seed surviving the

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winter to extremely low levels (Marquis et al. 1976). Because of this acorn shortage, shelterwood and other cutting methods have not stimulated natural regeneration. High deer populations even eliminate stump sprouts as a dependable source of regeneration. Attempts at direct seeding have not been promising due to depredation by rodents, even where individual acorns are protected (Marquis et al. 1976). White ash seed crops occur infrequently (Bjorkbom 1979), so there are few advance seedlings of white ash in most stands. These conditions led to an attempt to underplant northern red oak (*Quercus rubra* L.) and white ash (*Fraxinus americana* L.) seedlings to obtain adequate advance regeneration.

Although survival often is good, growth of planted oak seedlings in clearcuts and uncut stands has been poor--presumably because of deer browsing and unfavorable environmental conditions (Marquis 1974, Russell 1971, Johnson 1979). Underplanting red oak and white ash seedlings in shelterwood stands should provide more favorable conditions for seedling establishment than clearcuts and allow better growth than unthinned stands.

## METHODS

### Experimental Design and Analysis

The study was laid out in randomized blocks by the split-plot method; each species was analyzed separately. There were five blocks with three main plots per block. The overstory density treatments of 100, 60, and 30 percent of full stocking were assigned at random to the main plots. There were eight subplots consisting of the combinations of two species (red oak and white ash), two stock sizes (large and small), and two protection levels (protected from deer browsing and left unprotected). Twelve seedlings were planted in each subplot. Survival, growth, and browsing of the planted seedlings were measured in each of the next seven growing seasons. Diameter was measured until 1979. Only height data are presented due to the similarity between height and diameter patterns. In addition, each seedling was rated for freedom to grow in 1980 and 1981. Free-to-grow seedlings had to be tall enough so that a 90-degree cone mounted on the terminal did not intercept the foliage of a competitor. Seedlings were recorded as suppressed if completely overtopped by competitors and intermediate if intermediate between free to grow and suppressed. Averages of the surviving seedlings in each subplot were used in analysis of variance to test for significance of the treatment effects; arc-sine transformations of all percentage values were used. Student's t-test and LSD test were used to test for differences between treatments means.

Net height growth was calculated by subtracting the initial height of each seedling at planting or at time of overstory removal from the total height of each live seedling (sometimes a negative value). Net height growth under an overstory was the total of 3 years (1975-77) of growth that occurred while the seedlings were growing with residual overstory competition. Net height growth after overstory removal was the total of 4 years (1978-81) of growth after seedlings were released from overstory competition. Total net height growth was the total of 7 years (1975-81) of growth since planting, and included both periods under an overstory and after overstory removal.

## Field Plot Establishment

The study was located on the Tuscarora State Forest in south-central Pennsylvania. There were three blocks in Licking Creek Valley in Mifflin County and two blocks in Black Log Valley in Juniata County. Forest stands selected for plots were fully stocked oak stands of sawtimber size. They were dominated by varying proportions of black, red, scarlet, white, and chestnut oak that were 30 to 80cm (12 to 30 in) dbh. Some trees were 80 to 100cm (30 to 40 in) dbh. There were pole-size trees (15 to 30cm, 6 to 11 in dbh) of white oak, hickory, red maple, and sugar maple, along with a dense understory (2.5 to 15cm, 1 to 5 in dbh) of flowering dogwood, red maple, and sugar maple. Seedlings under 2.5cm (1 in) dbh were scarce and consisted mainly of red maple. Sawtimber-size and some pole-size trees made up an even-aged stand that was approximately 100 years old, while saplings and poles of red maple and sugar maple were in a younger age class. Soils at both locations were loamy-skeletal, mixed, mesic Typic Dystrochrepts of the Hazelton-DeKalb association. The site index was 21m (70 ft) for black oak.

Main plots were 60m by 60m (0.36 ha) (3 chains by 3 chains, 0.9 acre). Subplots were eight rows of 12 seedlings each in the center of each main plot. Planting rows were 2.4m (8 ft) apart with 1.8m (6 ft) between the seedlings in a row. A buffer of 19 to 20m (63 to 67 ft) surrounded the planting area within the main plot.

During the last 2 weeks in April, 1975, the main plots were thinned to the assigned overstory density and the timber removed. The actual average residual overstory densities for the five blocks were: 100 percent treatments--97.6 percent stocking, 25.5$m^2$/ha (110.9 $ft^2$/acre) basal area, and 548 trees per hectare (222 trees/acre); 60 percent treatment--61.5 percent stocking, 17.2$m^2$/ha (75.0 $ft^2$/acre) basal area, and 230 trees per hectare (93 trees/acre); 30 percent treatment--33.0 percent stocking, 9.6$m^2$/ha (41.8 $ft^2$/acre) basal area, and 94 trees per hectare (38 trees/acre). Stocking percentages were based on all trees 5cm (2 in) dbh and larger and determined from stocking charts in Roach and Gingrich (1968).

The seedlings were planted during the first 3 weeks in May, 1975, with nursery stock graded into large and small sizes. Average initial sizes are shown in Table 1.

Table 1.--Size of large and small red oak and white ash 1-0 planting stock used to underplant thinned hardwood stands.

| Stock Size | Red Oak | | White Ash | |
|---|---|---|---|---|
| | Height[1/] | Diameter[2/] | Height | Diameter |
| | cm | mm | cm | mm |
| Large | 39.6 | 5.6 | 33.5 | 6.8 |
| Small | 12.2 | 2.5 | 15.2 | 3.3 |

[1/] Height measured from ground line to terminal bud.
[2/] Diameter measured at 5cm (2 in) above ground line with machinist caliper.

Deer protection was provided at the time of planting by placing a chicken-wire cage, 0.3m (1 ft) in diameter by 1.2m (4 ft) tall, around each seedling and supporting it with stakes. As seedlings grew, these were replaced with 1.5m (5 ft) chicken wire.

During the winter of 1977-78, three growing seasons after the study was established, residual overstory trees were removed on all main plots, releasing seedlings from overstory competition. There was no weed control.

## RESULTS

### Survival

Deer browsing was the major factor affecting seedling survival of both species. Survival was significantly less ($P<.05$) both in 1977 while underplanted for 3 years, and in 1981, 4 years after overstory removal (Figure 1). Survival of unprotected red oak seedlings after overstory removal was not affected by deer browsing (curves of protected and unprotected seedlings are parallel), but this was not true for unprotected white ash seedlings (curves are not parallel). This phenomenon was not due to a lack of browsing, as height growth data show, but to red oak seedlings being able to withstand browsing after overstory release while unable to withstand browsing while underplanted. White ash seedlings showed no difference in ability to withstand browsing while underplanted or after overstory release.

Survival of unprotected seedlings was poor, so in further analyses only protected seedlings were used. Stock size had no effect on survival (Figure 2). White ash survival was unaffected by overstory density; however, red oak survival was significantly less ($P<.05$) under the 100 percent residual density than the 60 or 30 percent densities (Figure 3).

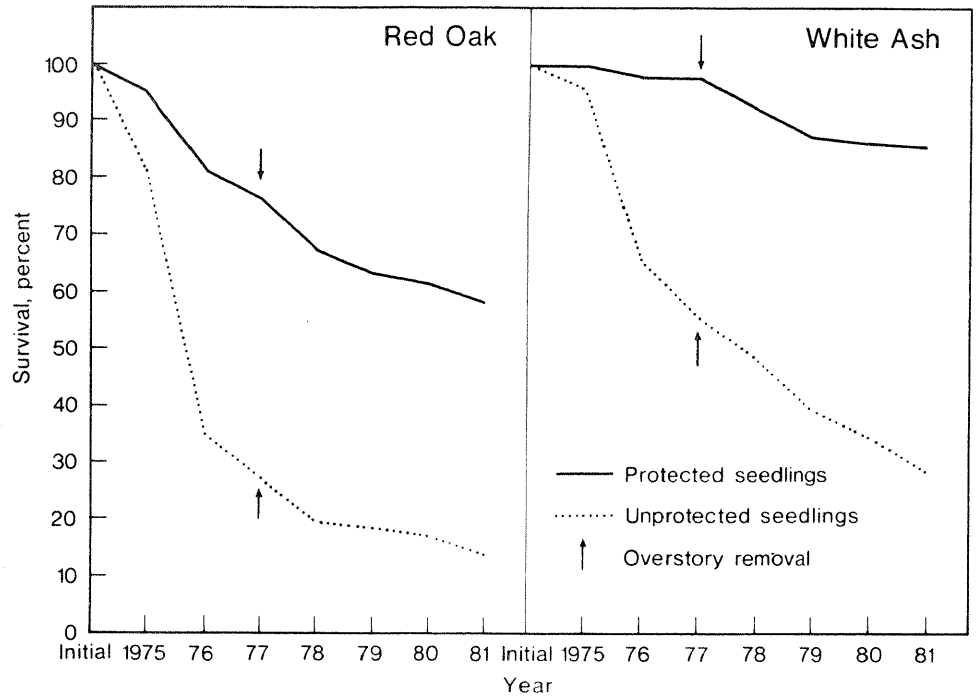


Figure 1.--Overall average survival curves of red oak and white ash seedlings as affected by protection from deer browsing.

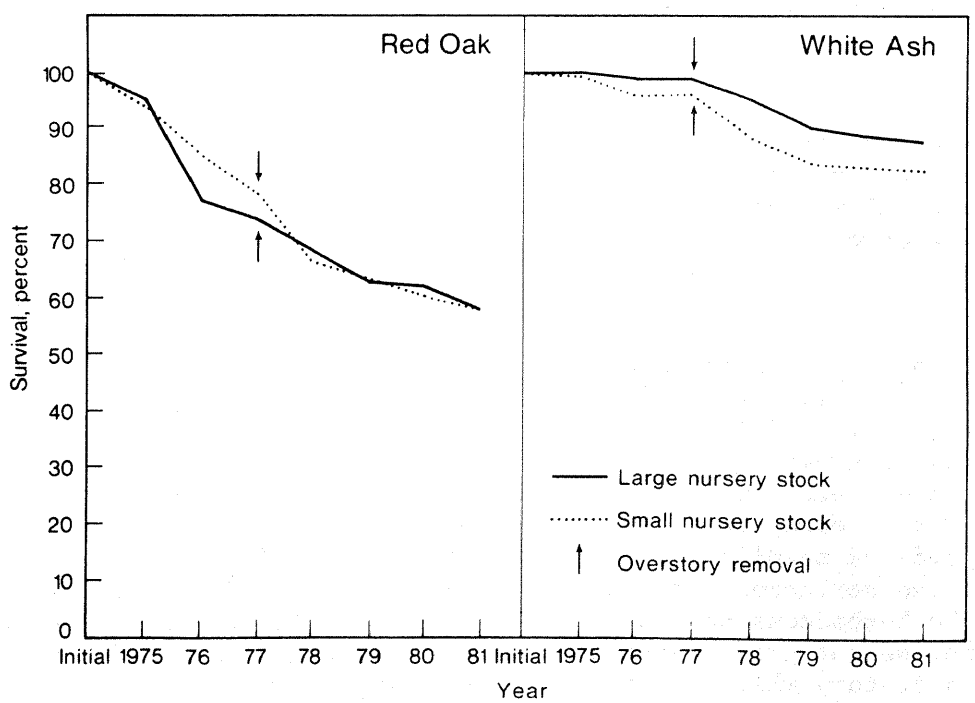


Figure 2.--Overall average survival curves of protected red oak and white ash seedlings as affected by nursery stock size.

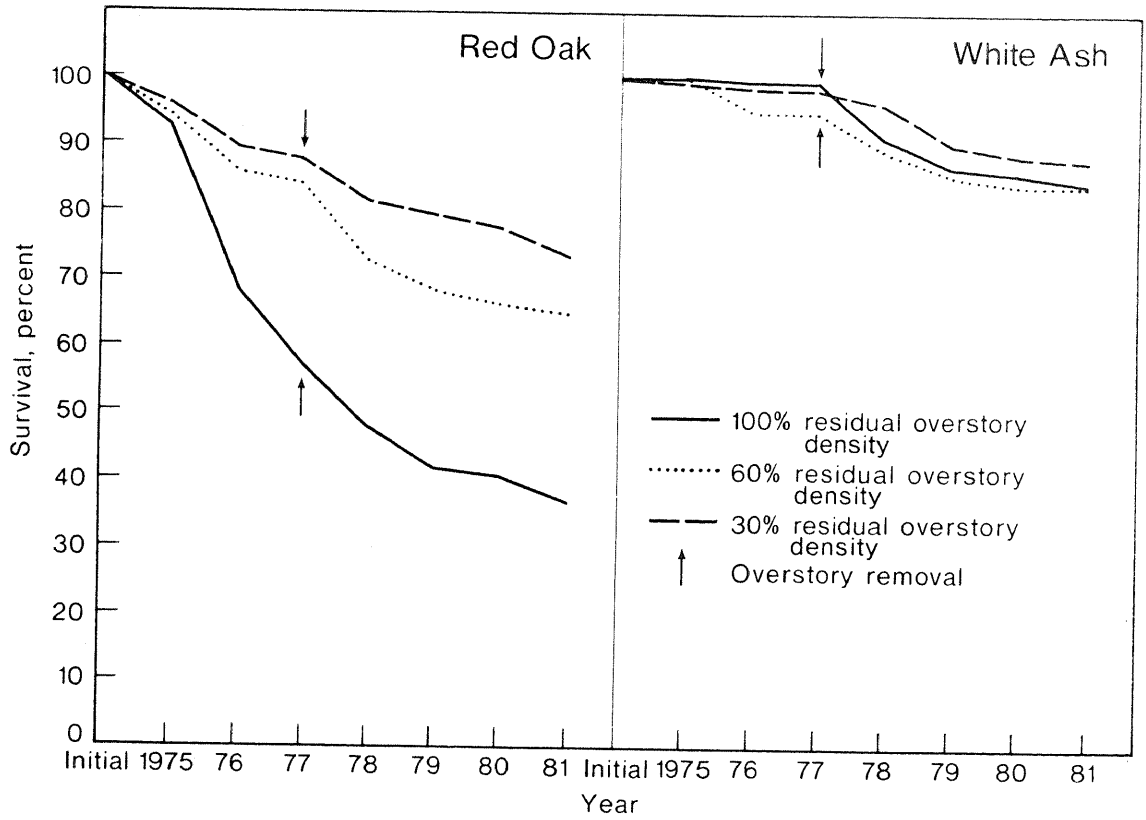


Figure 3.--Overall average survival curves of protected red oak and white ash seedlings as affected by residual overstory density.

White ash had higher survival than red oak, regardless of treatment. Survival was good for both species when the seedlings were protected. White ash survival was good under all overstory treatments, but red oak survival was good only under the two shelterwood densities.

## Height Growth

Protection was the most important factor affecting the height of seedlings of both species. Protected seedlings were significantly taller ($P<.05$) both in 1977 and in 1981 (Figure 4). While underplanted for 3 years, net height growth was negative for unprotected red oak seedlings, resulting in a decrease in height to the level of the herbaceous understory (Table 2). For 4 years after overstory removal, net height growth of unprotected red oak seedlings increased so that the seedlings remained at the level of the herbaceous understory. Deer browsed the seedlings as they grew above the herbaceous understory. Unprotected white ash seedlings also had little net height growth--these seedlings remained at the level of the herbaceous understory while the protected seedlings grew (Table 2).

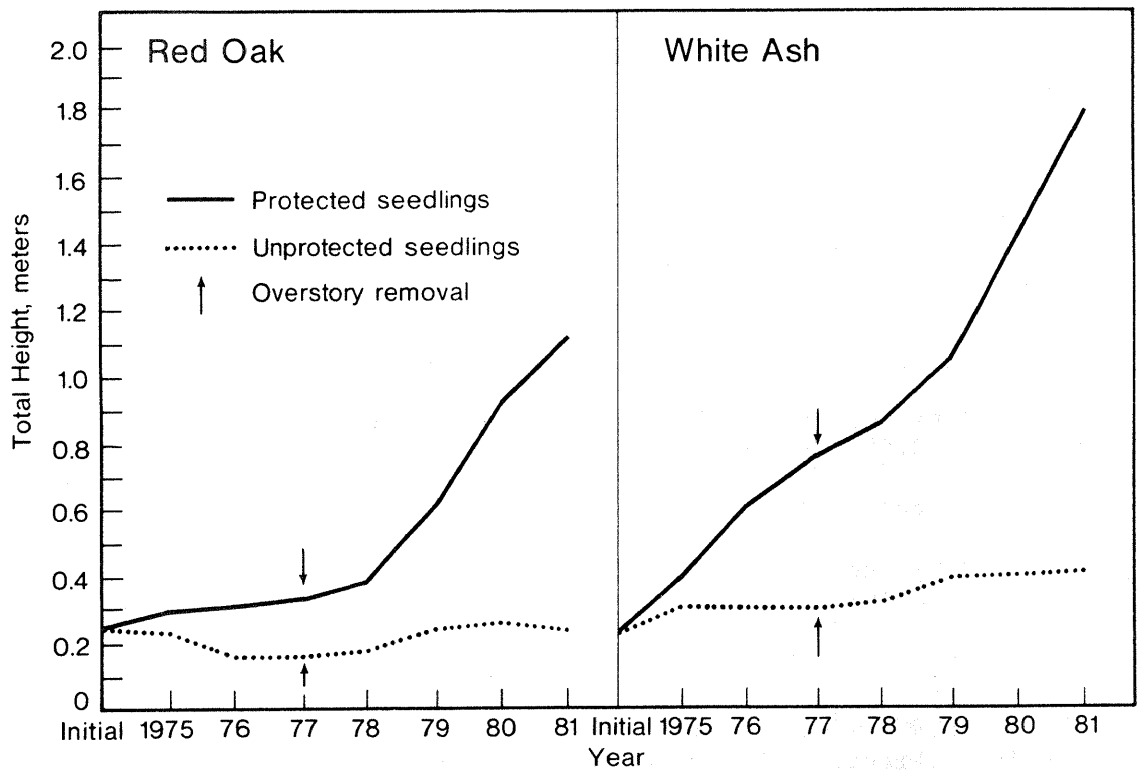


Figure 4.--Overall average height curves of red oak and white ash seedlings as affected by protection from deer browsing.

Table 2.--Overall average net height growth for 3 years (1975-77) after planting under an overstory (UO), 4 years (1978-81) after overstory removal (AOR), and 7 years (1975-81) after planting, by treatment.

| Treatment | Red Oak | | | White Ash | | |
|---|---|---|---|---|---|---|
| | UO | AOR | Total | UO | AOR | Total |
| | | | cm | | | |
| Protection[1/] | | | | | | |
| Fenced | 7.6a | 72.8a | 80.5a | 52.1a | 100.6a | 153.0a |
| Unfenced | -4.9b | 5.5b | 0.6b | 6.1b | 8.5b | 14.6b |
| Stock Size[1/2/] | | | | | | |
| Large | 3.4a | 70.4a | 73.5a | 57.0a | 112.2a | 169.2a |
| Small | 11.6b | 75.3a | 87.2a | 47.2a | 89.3b | 136.6b |
| Residual Density[2/3/] | | | | | | |
| 100 percent | 0.0a | 57.3a | 57.6a | 24.1a | 102.1a | 126.2a |
| 60 percent | 10.1b | 85.6a | 95.7b | 63.1b | 98.4a | 161.5ab |
| 30 percent | 12.2b | 75.6a | 88.1ab | 69.5b | 101.5a | 171.0b |

[1/] Means followed by the same letter are not significantly different from each other ($P \geq 0.05$) within a column and treatment by Student's t-test.

[2/] Protected seedlings only.

[3/] Means followed by the same letter are not significantly different from each other ($P \geq 0.05$) within a column and treatment by LSD test.

Stock size had a significant ($P<.05$) effect on white ash height in 1977 and in 1981 (Figure 5). The net height growth of white ash while underplanted was not significantly different, but after overstory removal there were significant differences between the two stock sizes (Table 2). The initial size advantage of large stocks over small increased only slightly while underplanted, but after overstory removal the large stock grew much better. But for red oak height, stock size was significant ($P<.05$) only in 1977 (Figure 5). Net height growth while underplanted was significantly different for small and large red oak stock, but after overstory removal, the differences were not significant (Table 2). Small red oak stock grew better than large stock while underplanted so that initial differences in size gradually decreased. Since release from the overstory, red oak of both stock sizes has grown at a similar rate.

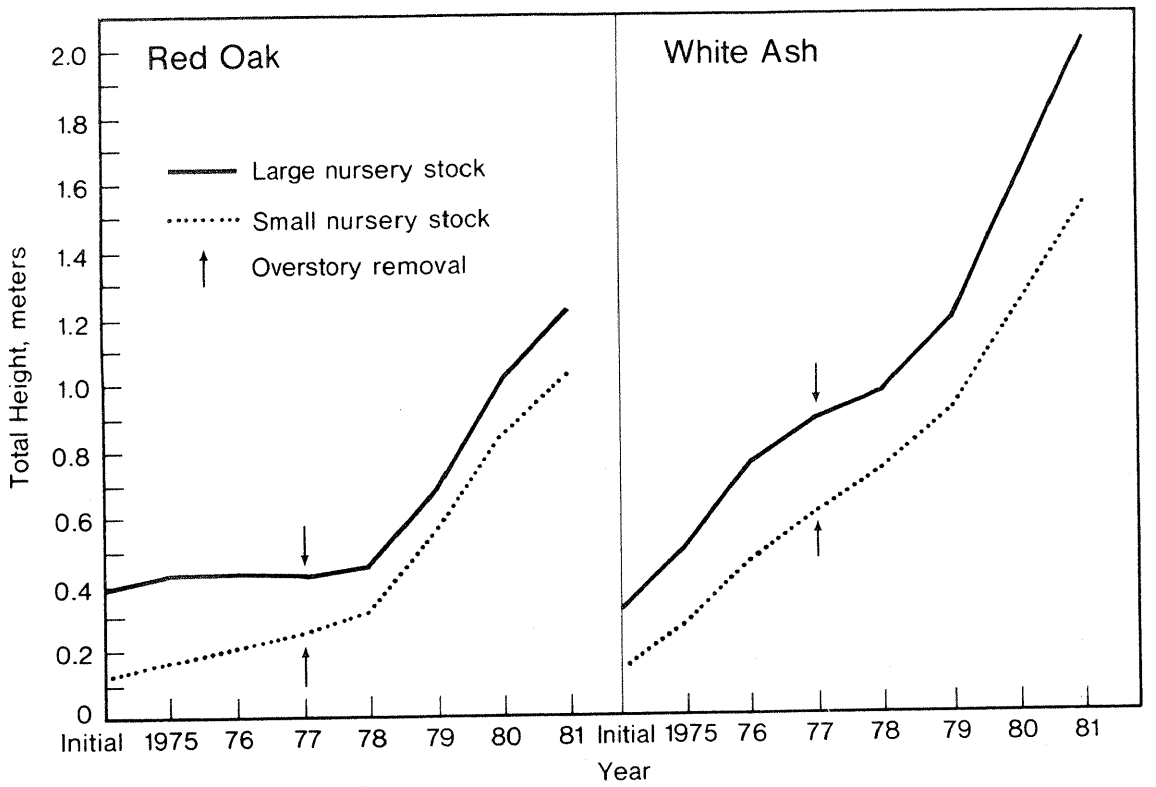


Figure 5.--Overall average height curves of protected red oak and white ash seedlings as affected by nursery stock size.

Residual overstory density significantly (P<.05) affected total height of white ash in both 1977 and 1981 (Figure 6). The net height growth of white ash seedlings while underplanted was significantly different but it was not significantly different after overstory removal (Table 2). Seedlings under 100 percent residual overstory density were shorter and had less height growth while underplanted than those under 60 and 30 percent densities. The response was similar for red oak. Seedlings under 30 and 60 percent residual overstory densities were significantly (P<.05) taller than those under 100 percent density (Figure 6), and had greater net height growth (Table 2).

White ash seedlings were taller and had greater net height growth than red oak, regardless of treatment. Height growth was greater when seedlings were protected from deer browsing and growing under reduced overstory density, but it was less under uncut conditions. After release from the overstory, growth was greater for all protected seedlings. Large white ash nursery stock performed better than small stock.

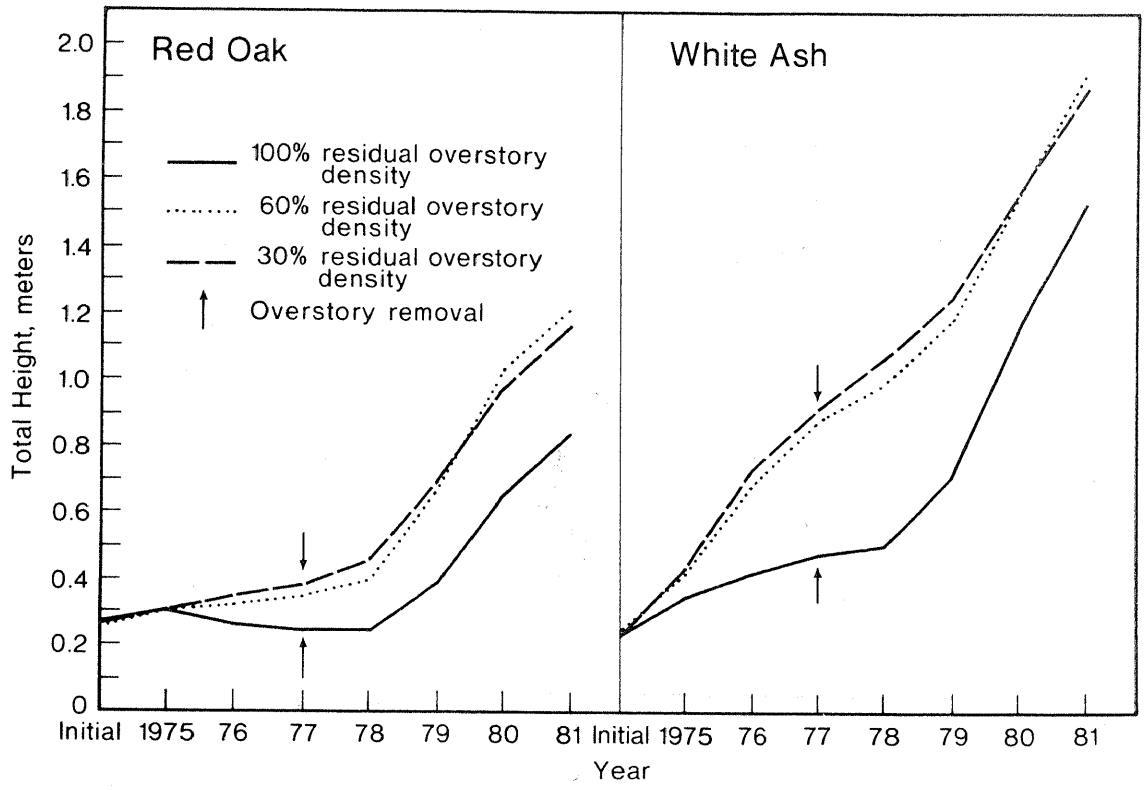


Figure 6.--Overall average height curves of protected red oak and white ash seedlings as affected by residual overstory density.

## Interference

Black locust (Robinia pseudoacacia L.) and tree-of-heaven (Ailanthus altissima (Mill.) Swingle) invaded a number of plots, especially the 30 and 60 percent plots in Licking Creek Valley. Tree-of-heaven, in particular, grew well under the 30 percent overstory density; since overstory removal, it has grown rapidly and interfered heavily with the planted seedlings. The 100 percent overstory density had no invasion until after overstory removal; therefore, interfering woody plants were not as severe in those plots or in the plots in Black Log Valley.

Protection from deer browsing resulted in significantly more free-to-grow seedlings than were found among the unprotected seedlings (Table 3). Unprotected seedlings were seldom dominant due to repeated browsing by deer, while 39 percent of the protected red oak and 58 percent of the protected white ash seedlings were free to grow. Stock size and residual overstory density had no significant effect on seedling dominance for protected seedlings, though there was a trend for fewer red oak seedlings

to be in a free-to-grow or intermediate position under 30 percent residual overstory density than under higher densities. This trend might have been significant if all blocks had been invaded equally by black locust and tree-of-heaven. The 30 percent residual density plots had fewer free-to-grow and intermediate seedlings than the 60 percent plots--even though the seedlings were the same height--because the interfering woody plants were taller in the 30 percent plots. The 100 percent residual density plots had the same number of free-to-grow and intermediate seedlings as the 60 percent plots, even though the seedlings were shorter, because the interfering woody plants were shorter in the 100 percent plots.

Table 3.--Overall average percentage of seedlings living in 1981 that are free to grow (FTG) and intermediate (INT) 7 years after planting, by treatment.

| | Red Oak | | White Ash | |
|---|---|---|---|---|
| Treatment | % FTG | % INT | % FTG | % INT |
| Protection[1/] | | | | |
| Fenced | 39a | 20a | 58a | 16a |
| Unfenced | 6b | 16a | 2b | 22b |
| Stock Size[1/2/] | | | | |
| Large | 42a | 18a | 66a | 13a |
| Small | 36a | 21a | 50a | 19a |
| Residual Stocking[2/3/] | | | | |
| 100 percent | 42a | 22a | 62a | 16a |
| 60 percent | 45a | 25a | 61a | 21a |
| 30 percent | 29a | 12a | 52a | 11a |

[1/] Means followed by the same letter are not significantly different from each other ($P \geq 0.05$) within a column and treatment by Student's t-test.

[2/] Protected seedlings only.

[3/] Means followed by the same letter are not significantly different from each other ($P \geq 0.05$) within a column and treatment by LSD test.

## DISCUSSION

### Protection Against Deer

The impacts of high deer populations (Marquis 1974, 1981, Marquis and Brenneman 1981) and the need to protect regeneration in Pennsylvania to ensure success have been documented (Marquis 1977, Marquis and Crisez 1978). The results of this study also show the need to protect underplanted red oak and white ash seedlings to ensure similar success. In Wisconsin, Scholz (1964) obtained similar results for fenced and unfenced red oak seedlings, but most of the damage was from rabbits. Wallihan (1949) and Stoeckler and Limstrom (1950) reported severe deer browsing on red oak and white ash seedlings in New York, Wisconsin, and Michigan.

### Overstory Density

There have been few underplanting trials with hardwoods. Chapman and Lane (1951), Deitschman (1956), and Bey and Woerheide (1963) studied red oak that had been planted under black locust, shortleaf pine, and sassafras, and in old fields. Survival was good under pine and sassafras and poor under black locust, while height growth was best under locust. The overstories never were removed. Red oak planted under loblolly pine had good survival after 3 years, but height growth was poor and damage from rabbits was severe (Wells 1964). White and black oak planted under shelterwood cuttings had rates of survival and height growth that were similar to or better than those of oak planted in adjacent clearcuts (Russell and Rollins 1969).

Johnson and Rogers (1982) underplanted red oak seedlings in partially cut stands and clearcuts. The overstories were removed after 3 years. One year after overstory removal, the underplanted seedlings were as tall as seedlings planted in the clearcuts; survival also was similar. The growth of white ash seedlings was better under stands cut to 80 percent residual density than in stands cut to 60 percent density or left uncut (Leak 1963). Logan (1973) reported greater height growth of white ash at 45 percent of full light than at lower or higher values. White ash seedlings were planted under plantations of black locust and shortleaf pine, and on open strip-mined land. After 3 years, survival was better for the underplanted seedlings than for the open-grown seedlings, but height growth was better for the open-grown seedlings (Deitschman 1950). Beck (1970) reported no height growth on natural red oak seedlings under an uncut overstory, while seedlings released by complete overstory removal increased in height. It is obvious from the literature and this study that underplanting will not be successful in uncut, high-density stands. However, shelterwood cut stands--those in which a portion of the overstory is removed--appear to favor the establishment and growth of seedlings. Once established, the seedlings can be released from the overstory. They will compete successfully with other woody vegetation that is not eliminated by deer browsing, as are most naturally occurring stump sprouts.

## Stock Size

Most research has shown that large nursery stock generally does better than small nursery stock. Indeed, for white ash, large stock performs better (von Althen 1969, Johnson 1971, 1976). For red oak it is not clear what size of stock is best or if there really are differences in field performances among size classes. However, differences in observed field performances of red oak may be due in part to differences in the physiological quality of nursery stock (Johnson 1981). In some cases, small red oak stock performed better than large stock, perhaps because of excessive root pruning (Scholz 1964, Wendell 1980, Beckjord and Cech 1980). In other cases, no differences were found between stock sizes (Foster and Farmer 1970, von Althen 1969, Olson and Hooper 1968, 1972, Loftis 1979). In still other cases, large stock or 1-1 transplants performed better (Larson 1977, Johnson 1971, 1976, 1981). The root/shoot ratio of red oak planting stock may be the determining factor in the success of the stock (Johnson 1981, Johnson and Rogers 1982).

## Interference

Interference from natural woody vegetation can prevent planted seedlings from becoming dominant on a site. In a southern Wisconsin clearcut, about 36 percent of the white ash and 12 percent of the red oak 1+1 transplants were codominant or larger 8 years after planting (Johnson 1976). In West Virginia clearcuts, 23 percent of the red oak seedlings were dominant, 23 percent were intermediate, and the remainder were overtopped 7 years after planting (Wendell 1979). In North Carolina, only 3.5 percent of the red oak seedlings were dominant or codominant 11 years after planting (Loftis 1979), while in Ohio, 18 percent were dominant or codominant, 25 percent were intermediate, and 57 percent were suppressed 13 years after planting (Hilt 1977). The release of red oak seedlings from understory interference after overstory removal resulted in an increase in height growth over unreleased seedlings (Beck 1970).

The use of underplanting has resulted in a larger number of dominant seedlings, especially for red oak, than planting in clearcut areas. The apparent reason for this is that the underplanting allows the seedlings to become well established before being exposed to the severe competition (any negative interaction between vegetation) and environmental conditions of a clearcut. The underplanted seedlings are then better able to survive and compete than seedlings planted directly into clearcuts. It is important not to reduce overstory density to the point where interfering vegetation is allowed to develop, as in the 30 percent residual overstory density used here.

# CONCLUSIONS

Underplanting can be used to successfully regenerate areas lacking adequate advance regeneration and seed sources so long as the seedlings are protected from deer browsing. The moderate overstory density created by shelterwood cutting allows planted seedlings to become established before

the overstory is removed. When released, a large proportion of seedlings are able to compete with other woody vegetation and maintain themselves in the new stand. We recommend underplanting both red oak and white ash under 60 percent residual overstory density for several years, and that seedlings be protected from deer. At the minimum, 865 seedlings per hectare (350 seedlings per acre) of red oak or 500 seedlings per hectare (200 seedlings per acre) of white ash should be planted to obtain 250 free-to-grow seedlings per hectare (100 free-to-grow seedlings per acre) 7 years after planting. Approximate spacings of 3.0 by 3.7m (10 by 12 ft) for red oak and 4.6 by 4.6m (15 by 15 ft) for white ash should be used.

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