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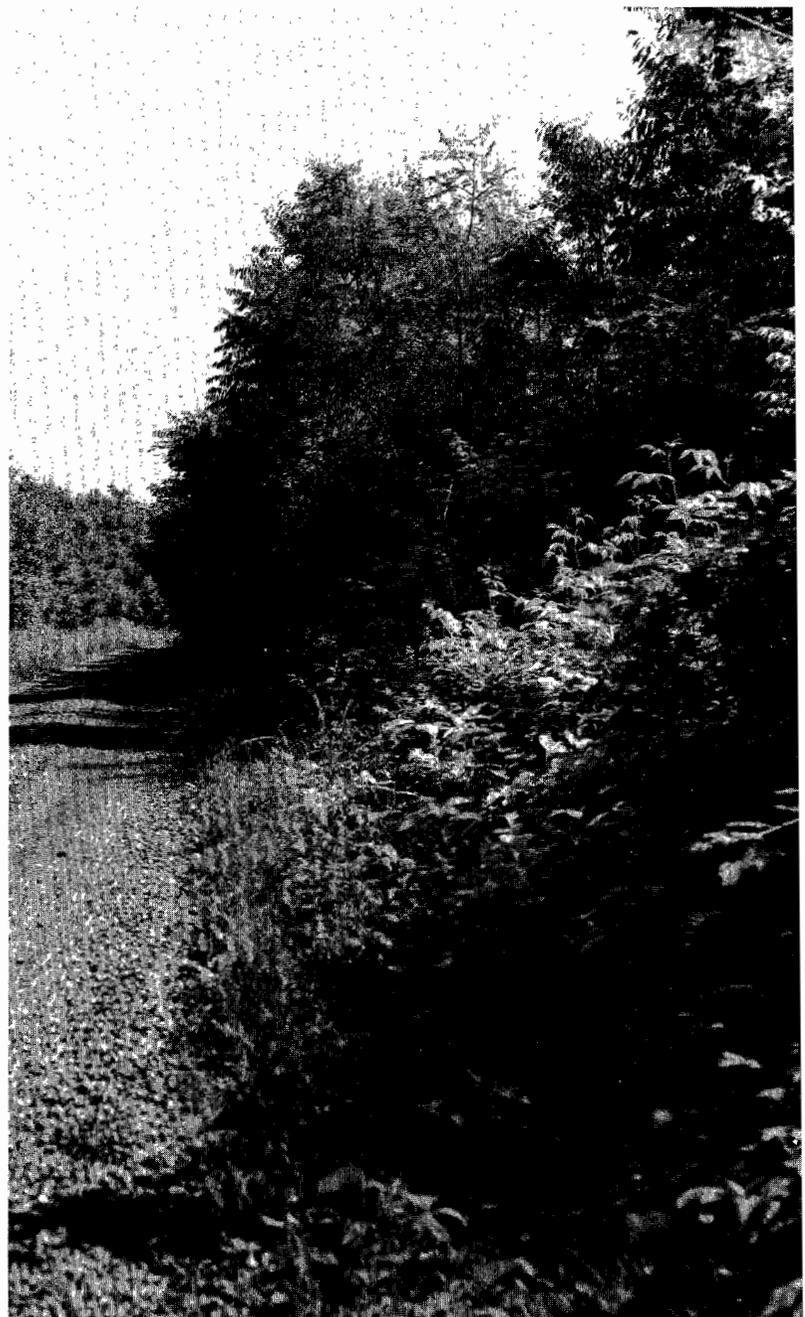
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Age and Stem Origin of Appalachian Hardwood Reproduction Following A Clearcut and Herbicide Treatment

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Abstract

Seven years after a clearcut and herbicide treatment in a West Virginia stand of Appalachian hardwoods, root and stem ages were determined for sugar maple, black cherry, and white ash. Age was used to verify origin and origin was used to evaluate reproduction stem development 7 years after clearcutting. Sugar maple stems originated from advanced reproduction; black cherry originated primarily from seedlings that germinated during or after treatment; and white ash stems were a mixture of seedlings, advanced reproduction, and stump sprouts.

Introduction

This paper is based on a reproduction study of hardwood stem development 7 years after clearcutting. It provides insight into the influence of origin or crown class for three valuable hardwood species. The results have implications that apply to areas of similar site and stand characteristics and silvicultural treatment.

The main objective of this study was to identify reproduction origin class and relate it to total stem height and groundline diameter (primarily for trees in the dominant-codominant crown class) 7 years after clearcutting. A second objective was to use root and stem shoot ages to verify when the reproduction was established. Intermediate and overtopped trees were also evaluated. The hardwood species studied were sugar maple (*Acer saccharum* Marsh.), black cherry (*Prunus serotina* Ehrh.), and white ash (*Fraxinus americana* L.). Reproduction originated from seed, stump sprouts, and advance reproduction. Advanced reproduction was further divided into four classes: seedlings, seedling-sprouts (new), seedling-sprouts (old), and advanced stems.

A number of studies have dealt with the origin of hardwood reproduction after clearcutting (Sander and Clark 1971; McGee and Hooper 1970; McQuilken 1975). Many variables, such as site quality, species composition, and density of the stand before harvesting, affect the reproduction characteristics of the new stand of trees. The study reported here should provide a better understanding of some of these factors and additional information for developing methods to improve species composition. With certain desired species, it is necessary to have advanced reproduction established before harvesting. In other instances, desired species are established after a harvest cut from seed accumulated in the soil.

Study Area

The study area is on the Fernow Experimental Forest near Parsons, West Virginia, maintained by the U.S. Forest Service, Northeastern Forest Experiment Station. The present forest type is mixed Appalachian hardwoods with a site index for red oak of 74 feet at 50 years.

Stand History

The forest was first logged about 1910. It was high-graded, a common logging practice during that period, and many unwanted trees were left. The next disturbance to the forest was the removal in the 1940's of dead stems of American chestnut (*Castanea dentata* (Marsh.) Borkh.) killed during the 1930's by the chestnut blight (*Endothia parasitica*).

Partial cuttings were made in 1958, 1963, and 1968. These light cuttings removed 14, 9, and 6 percent, respectively, of the basal area in trees 5.0 inches or more in d.b.h. The stand was then clearcut between July 1969 and May 1970, and all stems 1.0 to 4.9 inches d.b.h. were sprayed at the

base with 2, 4, 5-T. Because small stems were treated with herbicide rather than cut, some potential stems of stump sprout origin were eliminated from the future stand. Trees larger than 5.0 inches d.b.h. were cut. After the removal of sawlogs and pulpwood, only a few living trees between 1.0 and 4.9 inches d.b.h. escaped the herbicide and remained in the stand. Most of the advanced reproduction remaining was less than 1.0 inch in d.b.h.

Stand Description

At the time of clearcutting, the main stand was about 60 years old and had a volume of 7,928 board feet per acre (International 1/4-inch rule) in trees over 11.0 inches d.b.h. The basal area was 95 square feet in trees over 5.0 inches d.b.h. Before cutting, trees over 5.0 inches d.b.h. totaled 152 per acre and were mainly chestnut oak (*Quercus prinus* L.), red maple (*Acer rubrum* L.), northern red oak (*Quercus rubra* L.), sweet birch (*Betula lenta* L.), and Fraser magnolia (*Magnolia fraseri* Walt.). Also, some sugar maple and black cherry and a few white ash were present.

The large advance reproduction, stems 1.0 to 4.9 inches d.b.h., totaled 475 stems per acre before cutting and was dominated by American beech (*Fagus grandifolia* Ehrh.) with 145 stems per acre, followed by downy serviceberry (*Amelanchier arborea* (Michx F.)) and sugar maple, each averaging 70 stems per acre. White ash and black cherry were minor components of the large reproduction (about 5 trees per acre). Small advance reproduction, 1.0 foot in height to 0.9 inch in d.b.h., totaled about 3,200 stems and was dominated by sugar maple (710 stems per acre), American beech (400), red maple (330), and sassafras (*Sassafras albidum* (Nutt.) Nees.) (265 stems per acre). White ash and black cherry small advanced reproduction averaged about 100 stems per acre.

During the 7th year after clearcutting, a reproduction inventory found more than 4,000 overstory sapling stems per acre (Fig. 1). Black cherry, yellow-poplar, sugar maple, staghorn sumac (*Rhus typhina* L.), white ash, and black locust (*Robinia pseudoacacia* L.) were the most common overstory species.

Study Methods

Seven years after treatment, approximately 50 dominant-codominant sugar maple, black cherry, and white ash trees were selected at random for study. For the intermediate-overtopped crown class, more than 30 stems were sampled per species, except for black cherry, of which few stems were present. All sample trees were at least 4.5 feet tall. The general overstory stand canopy ranged from 12 to 20 feet high. Study trees were selected with compass line transects randomly established throughout the study area.



Figure 1A. Study area after clearcutting. B. Seven years later the overstory stems averaged more than 4,000 per acre.

Field Procedure. Species and crown class were recorded for each randomly selected sample stem. The roots of each sample tree (except stump sprouts) were exposed to a depth of about 6 inches below the root collar. Roots were then cut off, leaving 3 to 4 inches of root attached to the stem. Total height of the stem shoot was measured from the root collar to the tip of the terminal leader.

A different method was used in collecting stump sprouts. Sprouts from stumps greater than 2.0 inches in diameter at the groundline were cut off at the union with the stump. Diameter of the stump at the groundline (inches) and height of origin of the sprout on the stump (feet) were recorded. Where there were multiple sprouts, the tallest sprout was sampled. Sprout height was measured from the union of the sprout and stump to the tip of the terminal leader.

Laboratory Procedure. In the laboratory, the age of the stems and roots was determined by sectioning and detailed stem analysis, including X-ray radiography where annual rings were difficult to determine (Renton et al. 1974).

Three stem-origin classes were recognized:

1. New seedlings—stems originating from seed during or after clearcutting.
2. Stump sprouts—sprouts occurring after clearcutting from stumps greater than 2.0 inches in diameter at groundline or from advance reproduction greater than 2.0 inches in diameter at groundline.
3. Advanced reproduction—stems that existed before clearcutting.
 - 3a. Advanced seedlings—root and stem same age and both older than 7 years.
 - 3b. Advanced seedling-sprout (new)—root older than 7 years, stem 7 years or younger.
 - 3c. Advanced seedling-sprout (old)—root older than stem, both root and stem older than 7 years.
 - 3d. Advanced stems—stem older than 7 years, age of root could not be determined.

Analyses. The number of stems in each of the three origin classes was determined for each species by crown class. Where possible, samples from different origin classes within each individual species were tested for significant differences at the 5 percent level. Differences in 7-year total height and groundline stem diameter among the origin classes, other than stump sprouts, were tested for statistical significance by a one-way analysis of variance. Only stems in the dominant-codominant crown class were used for these 7-year growth comparisons, as these taller stems were considered to have grown freely throughout the 7-year period.

Ten different forms of simple regression equations were used to determine whether there were significant relationships between 7-year total height of advance reproduction

and groundline diameter at the time of clearcutting. Sometimes data from all available crown classes were used for the regression analyses, and in some cases, the samples were so small that the analyses provided information trends only. Also, the data on seedlings of stump sprout origin were biased by the herbiciding of saplings during the initial treatment.

Results

Root and Shoot Age Relationships—The basis of stem origin

The root and shoot ages were determined for advanced seedlings and seedling-sprouts. Roots from stump sprouts were not aged. Root and shoot ages for dominant-codominant sugar maple were as follows:

9 advanced seedlings—root-shoots averaged 20 years, ranging from 9 to 37 years;

6 advanced seedling-sprouts (new)—roots averaged 19.5 years, ranging from 9 to 42 years; shoots were 7 years old or younger;

14 advanced seedling-sprouts (old)—roots averaged 24 years, ranging from 15 to 43 years; shoots averaged 16 years, ranging from 8 to 26 years (Table 1).

Root and shoot ages for dominant-codominant white ash were as follows:

5 advanced seedlings—root-shoots averaged 12 years, ranging from 9 to 16 years;

3 advanced seedling-sprouts (new)—roots averaged 13 years, ranging from 11 to 15 years, shoots 7 years or younger;

9 advanced seedling-sprouts (old)—roots averaged 21.5 years, ranging from 11 to 44 years, shoots averaged 16.5 years, ranging from 9 to 25 years (Table 1).

For black cherry, the average age of both roots and shoots of advanced seedlings was less than that for sugar maple and white ash. Root and shoot ages for dominant-codominant black cherry were as follows:

3 advanced seedlings—root-shoots were 11.5 years ranging from 10 to 13 years.

6 advanced seedling-sprouts (new)—roots were 12.5 years ranging from 8 to 17 years, shoots were 7 years or younger (Table 1).

Table 1.—Number of stems per root-stem age class for advanced reproduction.

Species	Crown class	Advanced seedlings					Advanced seed-sprt (new)					Advanced seed-sprt (old)									
		Age					Age					Age									
		<10	10-19	20-29	30+	Ave.	<10	10-19	20-29	30+	Ave.	<10		10-19		20-29		30+		Ave.	
R ^a	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S	R	S		
Sugar maple	D-C ^b	1	5	1	2	20.3	1	3	1	1	19.5	0	3	2	7	11	4	1	0	23.9	16.2
	I-O	0	4	1	0	17.8	1	3	2	1	19.1	0	1	11	12	7	5	0	0	21.3	16.4
Black cherry	D-C	0	3	0	0	11.7	2	4	0	0	12.3	0	0	1	2	1	0	0	0	21.3	16.4
	I-O	1	1	0	0	9.0	0	1	0	0	12.0										
White ash	D-C	2	3	0	0	12.0	0	3	0	0	13.3	0	2	5	4	2	3	2	0	21.7	16.3
	I-O	0	1	0	0	11.0	1	1	0	0	11.5										

^aR = Root; S = Stem^bD-C = Dominant-codominant crown class

I-O = Intermediate-overtopped crown class

Table 2.—Seven-year total heights and groundline diameter^a by species, origin class, and crown class.

Species	New seedlings			Adv. seed.			Advanced seedling-sprout						Adv. stems			Stump sprouts			
	No. stems	7-Yr		No. stems	7-Yr		(New)			(Old)			No. stems	7-Yr		No. stems	7-Yr		
		Ht.	Dia.		Ht.	Dia.	No.	Ht.	Dia.	No.	Ht.	Dia.		Ht.	Dia.		Ht.	Dia.	
		ft	in		ft	in		ft	in		ft	in		ft	in		ft	in	
DOMINANT-CODOMINANT CROWN CLASS																			
Sugar maple	—	—	—	9	14.5	1.3	6	12.4	1.7	14	13.9	2.0	15	16.2	2.4	5	14.6	1.9	
Black cherry	36	14.9	1.3	3	22.0	2.7	6	17.8	1.7	2	20.0	2.0	—	—	—	1	20.7	3.0	
White ash	23	12.4	1.4	5	16.0	1.9	3	13.3	2.0	9	15.2	1.6	2	20.0	3.8	9	17.1	1.8	
INTERMEDIATE-OVERTOPPED CROWN CLASS																			
Sugar maple	—	—	—	5	8.7	0.8	7	8.9	0.7	18	9.3	0.8	1	14.2	1.0	2	10.6	1.2	
Black cherry	9	12.3	0.8	2	12.2	0.7	1	14.3	1.0	—	—	—	—	—	—	—	—	—	
White ash	33	7.8	0.6	1	8.9	0.8	2	12.6	0.9	—	—	—	—	—	—	—	—	—	

^aGroundline stem or stump sprout diameter.

Predicting total height using groundline stem diameter

Only two advanced seedling-sprouts (old) of black cherry were measured and the roots were 13 and 21 years old, while the shoot ages were 10 and 18, respectively. Though a few black cherry roots and shoots of advanced reproduction were 15 years plus, most of the roots were about 10 years old, indicating that the more intolerant black cherry do not normally live as long as the sugar maple or white ash in the undisturbed stand.

Origin of stems by crown class. A total of 82 sugar maple stems were sampled; of the 49 dominant-codominant stems, 41 percent were advanced seedling-sprouts and 18 percent were advanced seedlings (Table 2). Also, 31 percent of advanced stems could not be categorized as either seedlings or seedling-sprouts because of aging difficulties. No new sugar maple seedlings taller than 4.5 feet were sampled. Since stems less than 5.0 inches d.b.h. had been herbicided, few stump sprouts were found. Sixty-seven percent of the intermediate-overtopped sugar maple stems were advanced seedling-sprouts (Table 2). Advanced seedling-sprouts dominated the sugar maple reproduction origin class in the 7-year-old even-aged stand.

Black cherry and white ash had considerably more new stems of seedling origin than sugar maple. Of the 48 dominant-codominant black cherry stems sampled, 75 percent originated as new seedlings and 17 percent were advanced seedling-sprouts (Table 2). Similarly, of the 12 intermediate-overtopped black cherry stems, 75 percent were new seedlings. A total of 51 dominant-codominant white ash trees were sampled. From this total, 45 percent were designated new seedlings, and 24 percent were advanced seedling-sprouts (Table 2). Also, 36 white ash stems were in the intermediate-overtopped class and 92 percent of these stems were new seedlings.

Effect of stem origin on height and groundline diameter.

In general, for white ash and sugar maple, stump sprouts were as tall or taller than advanced seedlings, taller than advanced seedling-sprouts (old), and taller than advanced seedling-sprouts (new). For black cherry, the number of samples was too low for comparisons (Table 2). However, where present, the intolerant black cherry stems within a similar origin class were always taller than the white ash or sugar maple 7 years after clearcutting (Table 2).

After 7 years, dominant-codominant advanced seedling-origin stems had the smallest groundline stem diameter among sugar maple origin classes (Table 2). Groundline diameter for advanced black cherry seedling-sprouts (new and old) averaged about 0.5 inches more than new seedlings. Also, as expected, white ash advanced seedlings and seedling-sprouts were consistently larger in groundline stem diameter than new seedling reproduction.

Groundline stem diameter when the stand was cut was used to predict total height of advanced reproduction 7 years after clearcutting. We cannot recommend using groundline stem diameter to predict 7-year total height for advanced seedlings (excluding seedling sprouts). More data are needed.

For all sugar maple crown classes in the advanced seedling-sprouts (old and new) reproduction stem origin category the best regression, though significant, was low, with an R^2 of 0.41. Similar regressions for black cherry ($R^2 = 0.58$) and white ash ($R^2 = 0.77$) were significant too. Total height-initial groundline diameter regressions for advanced seedling-sprouts (new) from all crown classes improved slightly for sugar maple ($R^2 = 0.50$) and black cherry ($R^2 = 0.87$). All coefficients were significant. Too few data were available to calculate R^2 values for white ash.

In general, for advanced seedling-sprouts, data for black cherry and to a lesser degree white ash indicated that initial groundline stem diameter could be used as a predictor of 7-year total height. Many of the better regression equations were in the form:

$$Y = a \pm b (\log X)$$

where Y = Total height (7-year) in feet
X = Groundline stem diameter (initial) in inches
Log = Common log (base 10)

Using the equation for all crown classes of black cherry advanced seedling-sprouts (new),

$$Y = 20.184 + 9.059 (\log 0.5)$$
$$Y = 20.184 + 9.059 (-0.30)$$
$$Y = 17.5 \text{ feet}$$

thus if the initial groundline stem diameter was 0.5 inches the total height at 7 years would be 17.6 feet and the R^2 would be 0.87.

Data from all advanced stem origin classes were combined for all crown classes and separate equations developed for each species. Results indicate that prediction equations were acceptable for sugar maple ($R^2 = 0.73$) and white ash ($R^2 = 0.63$); however, the equation for black cherry ($R^2 = 0.22$) was poor. Thus, combining advanced seedlings with advanced seedling-sprouts for all crown classes and using the groundline diameter at clearcutting to predict total height 7 years later could be done for sugar maple and white ash stems.

By measuring groundline stem diameter for advanced reproduction when the stand was clearcut, we can make a rea-

sonable prediction of how tall a tree will be in the stand 7 years later. For example, if the groundline stem diameter of an advanced white ash stem was 0.8, the total height after 7 years would be estimated at between 11 and 12 feet (11.6 feet) when using the equation for white ash as indicated:

White ash $Y = 12.84 + 12.30 (\log X)$;
Sugar maple $Y = 10.51 + 14.57 (\log X)$;
Black cherry $Y = 20.91 + 6.12 (\log X)$.

However, we realize more data are needed to develop better equations for the stem origin categories. And once better equations are developed, the predicted values need to be verified with more field data.

Discussion

We recognize that the herbicide treatment had some effect on the availability of stems of stump sprout origin, but we cannot evaluate this effect. More stump-sprout origin stems would be expected from a normal clearcut than from a clearcut with herbicide. However, the root-shoot age for advanced reproduction would not be affected. The age of roots indicated that the small advanced sugar maple reproduction averaged about 20 years, but some roots were more than 40 years old. Tryon and Powell (1984) reported that advanced white ash seedlings were slightly younger than the sugar maples, but some advanced seedling sprouts were also more than 40 years old. Advanced black cherry seedling roots were considerably younger than those of sugar maple and white ash. Black cherry roots averaged about 12 years. In view of the age of advanced reproduction, classical silviculturists may consider revising their thoughts on even-aged and uneven-aged hardwood stands.

In this study, advance reproduction is the most important source of sugar maple stems; 90 percent of the dominant-codominant stems originated from advanced seedling-sprouts or seedlings. The establishment of new seedlings as a result of treatment was the major source of black cherry stems, accounting for 75 percent of the dominant-codominant stems. However, the origin of white ash stems was more evenly distributed: New ash seedlings accounted for 45 percent and advanced reproduction 37 percent of the ash reproduction. Thus, advanced reproduction plays a major role in stem development of sugar maple and white ash, but for black cherry, the development of new seedlings was a significant factor in this study. The recent periodic light thinning could have influenced the establishment and development of advanced regeneration, too.

The results of this study generally support earlier findings that species behavior is related to shade tolerance, crown class, and growth rates. These variables interact with differences in stand conditions and treatments.

Some meaningful regressions were found using initial groundline stem diameter to predict 7-year total height for advanced stems and advanced seedling-sprouts. However, more data and field verification of the predicted values are needed.

Sugar maple. Sugar maple is the most shade tolerant of the three species studied, and new seedlings failed to produce dominant-codominant trees 7 years after clearcutting. Smith (1983) found that even with annual removal of competing forest vegetation, small sugar maple stems did not maintain enough height growth after clearcutting to compete.

Winget (1968) in Quebec and Ostrom (1938) in Pennsylvania observed that sugar maple developed almost entirely from advance reproduction. Sugar maple is able to withstand several years of complete suppression and still respond to release (Downs 1946). However, small reproduction at the time of clearcutting cannot compete with the surge of faster-growing, more intolerant vegetation. Most of the sugar maple stems in even-aged stands in Pennsylvania were found to be old advance reproduction from sapling or small pole-sized advance reproduction (Marquis et al. 1975).

Black cherry. New black cherry seedlings grew well when released, faster than both sugar maple and white ash. Black cherry is the most shade-intolerant of the three species. Unlike sugar maples, many of the dominant-codominant black cherry stems 7 years after cutting originated from new seedlings. Several reproduction studies following clearcutting on sites similar to this study area indicate that black cherry is a consistent component of the new stands. In no instance were advance stems (1.0 to 4.9 inches d.b.h.) of this species present in any appreciable numbers unless the stands had previously been subjected to partial cuttings.

White ash. Less information is available for white ash than for the other two species, but it is intermediate in tolerance between the more tolerant sugar maple and less tolerant black cherry. White ash is also intermediate in total height growth rate between sugar maple and black cherry. In the seedling stage, white ash is generally tolerant and sprouts well, but it becomes more intolerant with increasing age (Wright 1965; Logan 1973). Logan (1973) also concluded that white ash seedlings grown in 87 percent artificial shade were as tall as those in full light, but the maximum dry weight was produced at 55 percent shade.

White ash seldom occurs in pure stands, and in West Virginia ash is rarely a major component of the stand. For example, in this study 46 percent of the dominant and codominant white ash reproduction came from new seedlings and 37 percent came from advanced reproduction. This suggests that ash could be present following either clearcutting or selection regeneration in these Appalachian mixed hardwood stands. However, as mentioned earlier, white ash is tolerant as a seedling but needs light after the seedling

stage. Therefore, where white ash occurs in the understory and is desired, the shelterwood method seems to be a logical natural regeneration method to increase the white ash component.

Silviculture research provides some information as to why certain species occur in given situations. Sugar maple can be grown under even-age management. Single-tree selection is also well suited to sugar maple, and the species can be grown by group selection and diameter-limit cuts, too.

Where black cherry is to be favored, even-age management is preferable because this species is shade intolerant and grows rapidly when young. The abundant seed crops and seeds which lie dormant for 3 to 4 years (Wendel 1977) usually provide for a source of advanced regeneration or new seedlings. The study reported here shows that black cherry seedlings were the main source of the dominant-codominant stems in the 7-year-old even-aged stand. Shelterwood is not needed to establish black cherry in this area, since good periodic seed crops and clearcutting will provide all the black cherry stems needed for the future stand.

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Caution

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first aid treatment given on the label, and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

NOTE: Some states have restrictions on the use of certain pesticides. Check your State and local regulations. Also, because registrations of pesticides are under constant review by the Environmental Protection Agency, consult your local forest pathologist, county agricultural agent, or State Extension specialist to be sure the intended use is still registered.

Trimble, G. R., Jr.; Tryon, E. H.; Smith, H. Clay; Hillier, J. D. **Age and stem origin of Appalachian hardwood reproduction following a clearcut-herbicide treatment.** Res. Pap. NE-589. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 1986. 8 p.

Seven years after a clearcut-herbicide treatment in a West Virginia Appalachian hardwood stand, root-stem age was determined for sugar maple, black cherry, and white ash. Sugar maple stems originated from advanced reproduction, black cherry originated primarily from seedlings that germinated during or after treatment, and white ash stems were a mixture of seedlings, advanced reproduction, and stump sprouts.

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Keywords: Regeneration, stem origin, stem age, clearcut-herbicide

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.**
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 - **Orono, Maine, in cooperation with the University of Maine, Orono.**
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