ODC 232.311.1:231.1:181.521.

by John C. Bjorkbom

Seed Production and Advance Regeneration in Allegheny Hardwood Forests

FOREST SERVICE RESEARCH PAPER NE-435
1979
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA. 19008

The Author

JOHN C. BJORKBOM is a research forester with the Northeastern Forest Experiment Station's Forestry Sciences Laboratory in Warren, Pennsylvania. He is currently engaged in research in the regeneration of Allegheny hardwoods.

MANUSCRIPT RECEIVED FOR PUBLICATION 2 NOVEMBER 1978

Abstract

The production of flowers and seeds of black cherry, red maple, sugar maple, and white ash and their relation to advance regeneration were observed from 1971 through 1976 on the Allegheny Plateau of northwestern Pennsylvania. There were good seed crops 1 year out of 2 for black cherry, 1 year out of 3 for red maple, and 1 year out of 6 for sugar maple. No white ash seed was produced. Flower crops were reliable indicators of seed crop size for the maples but not for black cherry. Both seed production and advance regeneration were related to basal area. Advance regeneration and basal area data were used to develop a guide to evaluate the adequacy of seed sources for the regeneration of Allegheny hardwood stands.

INTRODUCTION

ADVANCE REPRODUCTION is the key to success in regenerating Allegheny hardwood forests with valuable species such as black cherry, red maple, sugar maple, and white ash.[1] But in many areas, advance seedlings of these species are absent. The most likely reasons for this include lack of seed source, inadequate seed production, failure of seeds to germinate, and failure of seedlings to survive.

We know in a general way how often good seed crops develop, about how much seed can be produced, and when it is dispersed (U.S. Forest Service 1974). But less is known about the relationship between flower crops and seed crops. On a broader scale, we have little data on the interdependence of forest stands, seed production, and advance regeneration. Forest managers concerned with regenerating new stands need to know how species composition affects seed production, how seed production affects the number of new seedlings, and how long seedlings survive under the canopy of a closed stand.

To learn what these relationships are, I studied the characteristics of seed production of a number of Allegheny hardwood stands and the effects of seed crops on the advance regeneration.

THE STUDY AREAS

Two areas, each about 4 acres in size, were established in hardwood stands that originated about 1900 on the Allegheny Plateau. Neither area showed evidence of recent disturbance that might affect seed production; however, there were some differences between them.

In Area 1, the stand was 96 percent stocked, had an average stand diameter of 7.4 inches, and had a total basal area per acre of 136 ft^2, of which about 40 percent was in black cherry and 35 percent was in sugar maple.[2] The remainder was in red maple (15 percent), white ash (4 percent), and other species (6 percent).

In Area 2, the stand was 99 percent stocked and had an average stand diameter of 8.5 inches. The total basal area per acre was 153 ft^2, of which nearly 50 percent was in black

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

[2]In both areas, this includes all trees in the 1-inch diameter class or larger.

cherry and 35 percent was in sugar maple. There was little red maple (1 percent) and no white ash. The remaining basal area (15 percent), was in other species, principally beech.

METHODS

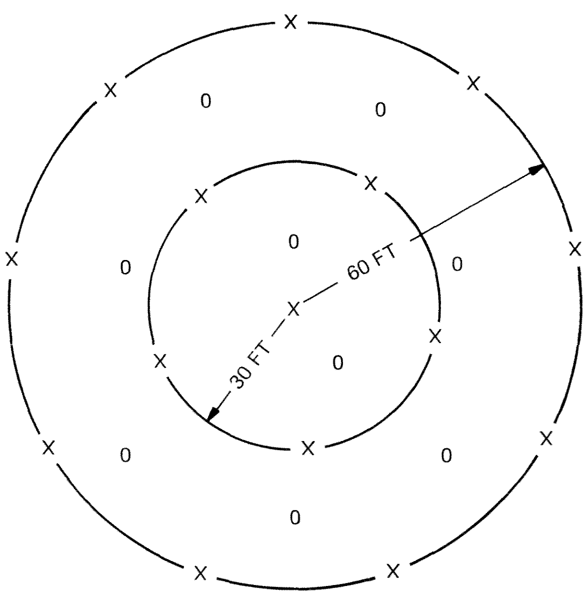
Seed production

In each area, 19 clusters of seed traps were located randomly. Distances among clusters were great enough so that little, if any, seed from a single seed tree was likely to be dispersed into more than one cluster. Each cluster was treated as a single stand.

Fifteen seed traps were systematically located in each cluster (Fig. 1). These traps were 6-inch diameter plastic flower pots fitted with perforated plastic bags. The traps, fastened to stakes, were 3 to 4 ft above the ground. To prevent seed pilferage by small mammals, 1-ft squares of aluminum were attached to the stakes (Fig. 2). Seed collections from these traps were used to estimate seed production, seed quality, and time of dispersal.

Figure 2.—A total of 285 seed traps such as this were used to estimate seed production.

Figure 1.—There are 15 seed traps (x) and 9 regeneration plots (o) in each cluster. Clusters are 60 feet in radius and encompass about 0.25 acres.



The trapping seasons covered the periods in which ripe seed was dispersed. The season for red maple extended from May 1 to June 30. For black cherry, sugar maple, and white ash, trapping began August 1 and ended November 30. During these periods, counts were made weekly from 1971 through 1973, but only at the end of the dispersal periods thereafter.

The basal area per acre of black cherry was estimated from inventories of 15-ft radius plots centered on each trap location. This radius was used because it is the crown radius of an 18-inch black cherry (Hough 1935)—the largest diameter tree that might be expected to be found with some frequency in the study stands—and the crown of this species, with its heavy seed, must overhang or be close to a trap for its seed to be caught.

Because the seeds of red maple and sugar maple are relatively light, they are dispersed much greater distances. Estimates of basal area per acre of these species were based on plots 120 ft in radius with the plot center used as the central trap location in each of the 19 clusters.

The amount of seed stored in the humus was estimated from 1-ft^2 blocks cut from the forest floor in early April. These blocks were maintained in a greenhouse where light, moisture, and temperature conditions favored seed germination. Germinants were counted by species as they appeared and, at the end of the growing season, the blocks were sieved to recover any sound ungerminated seeds.

Flower crops

Sample trees of black cherry, red maple, sugar maple, and white ash were selected in each seed production area (Table 1) for estimates of flower production. This was done to determine whether flowering estimates were good indicators of seed production.

Flower crops were rated according to the relative abundance of flowers borne on twigs or branches randomly selected in the upper crowns (Grisez 1975). Here, in my report, the crops were grouped as good to bumper, poor to fair, or trace to none. For red or sugar maple flower crops to qualify as good to bumper, more than half of the branches sampled had to have three or more flower custers. A good to bumper flower crop for black cherry averaged 33 flowers per sampled twig.

Regeneration

Regeneration tallies by species and height class of all stems below the 1-inch diameter class were made on 9 milacre plots in each of four clusters of seed traps in Area 1. The initial inventory was made in spring 1973. Thereafter, annual inventories were made at the end of each growing season from 1973 through 1976. At each inventory, seedlings were distinctively marked so that the year of origin (or age) would be known. In the May and September 1973 inventories, the number of seedlings was underestimated because the maximum number recorded was 99. Beginning with the 1974 inventory, the total number was recorded.

RESULTS AND DISCUSSION

Flower crops

Red maple flower crops were good to bumper in 4 years out of 6 from 1971 through 1976. In 1973 and 1976 there were untimely frosts that may have killed most of the flowers.

In the same period, a good to bumper black cherry flower crop was never recorded. This may have been the result of poor visibility rather than limited flowering—foliage of maple, beech, and other trees in the lower crown canopy obscured the cherry crowns that occupied dominant positions in the upper canopy. Also, there were frosts at this time and they may have destroyed the flower crops.

Table 1.—Number and diameter of sample trees by species and seed production area

Species	Area 1		Area 2	
	Number of trees	Diameter range (inches)	Number of trees	Diameter range (inches)
Black cherry	17	9.9-23.7	18	10.2-22.7
Red maple	11	9.8-16.3	5	11.9-17.9
Sugar maple	14	7.1-17.6	16	10.0-16.4
White ash	20	7.0-17.8	0	—

Sugar maple had only one good to bumper flower crop in the 6 years of observations. White ash failed to flower in that length of time.

Seed production

Seed production was not always of the same magnitude in both areas (Tables 2 and 3). This can be explained in part by differences in numbers of trees, basal area, and local weather conditions.

If the patterns of seed production reported here were to continue, good seed production for black cherry might be expected 1 year out of 2; for red maple, 1 year out of 3; and 1 year out of 6 for sugar maple. In these good seed years, seed production was estimated to average 507,000 black cherry seeds per acre and close to 450,000 seeds per acre for both red maple and sugar maple. No white ash seed was produced.

These expected frequencies of good seed years by species differ somewhat from those reported by others. Grisez (1975) reported less frequent seed years for black cherry, similar frequencies for red maple and sugar maple, and more frequent for white ash. Godman and Mattson (1976) recorded the same frequency for red maple seed years but more frequent large crops of sugar maple and white ash. The U.S. Forest Service (1974) reported greater frequencies for red maple, sugar maple, and white ash but fewer for black cherry. But the differences are small and probably arise from the dissimilar observational areas—two seed production areas for this study compared to large geographic areas or to the entire species range.

Flower vs. seed production

Red maple flower crops were good predictors of seed crops in 2 out of the 4 years in which seeds were produced—bumper flower crops were followed by abundant seed production. But in the other 2 years, good to bumper flower crops were followed by poor

Table 2.—Mean seed production per acre by species and year for Area 1[a] (thousands of seeds per acre)

Year	Black cherry	Red maple	Sugar maple
1971	78.6±69	38.0±42	1.3±208
1972	365.4±31	557.9±22	430.9±17
1973	336.6±37	0.0	0.0
1974	39.3±74	447.9±23	15.7±60
1975	597.2±25	83.8±42	0.0
1976	0.0	0.0	0.0

[a]Mean ± confidence limit in percent.

Table 3.—Mean seed production per acre by species and year for Area 2[a] (thousands of seeds per acre)

Year	Black cherry	Red maple	Sugar maple
1971	129.5±30	7.3±103	7.3±103
1972	583.5±33	408.9±12	464.2±26
1973	0.0	0.0	0.0
1974	397.3±27	112.0±53	13.1±71
1975	762.5±25	36.4±85	0.0
1976	72.8±76	0.0	0.0

[a]Mean ± confidence limit in percent.

seed years. Although the reasons for this are not clear, adverse weather may have limited pollination and fertilization; frosts may have killed many of the flowers or immature seeds. However, since flowering is followed so closely by fruiting, few benefits can be gained by predicting red maple seed crops from flower production.

Black cherry flower crops are not good indicators of the size of seed crops. Over the study period one-half of the flower crops were classed trace to none yet these flower crops were followed by seed crops that averaged an estimated 427,000 seeds per acre. In contrast, the other half of the flower crops were classed slightly better (poor to fair) and were followed by seed crops that averaged only about 103,000 seeds per acre. This disparity was the result of not only underestimated flower crops, but also the natural tendency of black cherry to flower abundantly but fruit poorly (Grisez 1975).

For sugar maple, only one flower crop was rated as good to bumper in each area, and each was followed by abundant seed. In the other 5 years, flower crops were rated trace to none and very little seed was produced. These results agree with those reported by Grisez (1975).

Seed dispersal

Seed dispersal was observed from 1971 through 1973. Almost all the red maple seed was dispersed in June, about three-fourths of the black cherry seed fell in August and September, and most of the sugar maple seed fell in October (Table 4). Seed dispersal depends on the environmental conditions under which the seed develops and matures, so the time of dispersal can—and does—vary considerably from year to year.

Table 4.—Percentage of total seed crop dispersed, by species, period, and year

Species and dispersal period	1971	1972	1973
Red maple			
June 1-15	0	78	—
June 16-30	98	20	—
July 1-10	2	2	—
Total	100	100	—[a]
Black cherry			
August	82	14	0
September	13	54	53
October	5	32	47
Total	100	100	100
Sugar maple			
August	—	2	—
September	—	5	—
October	—	78	—
November	—	15	—
Total	—[a]	100	—[a]

[a]Seed crop too small for reliable estimate.

Seed quality

To know how much seed is produced is only part of the story. It is just as important to know how good it is. I used seed soundness as a measure of seed quality, and a sound seed was assumed to be one that has the potential to germinate.

Estimates of black cherry seed quality were made by removing the seed coat and examining the seed for evidence of any damage that might affect the viability of the seed. Maple samaras were checked for external evidence of damage and to determine whether their seeds were fully developed. Based on these observations, seed soundness for the period 1971 through 1976 was estimated to be:

Black cherry	91 percent
Red maple	82 percent
Sugar maple	56 percent

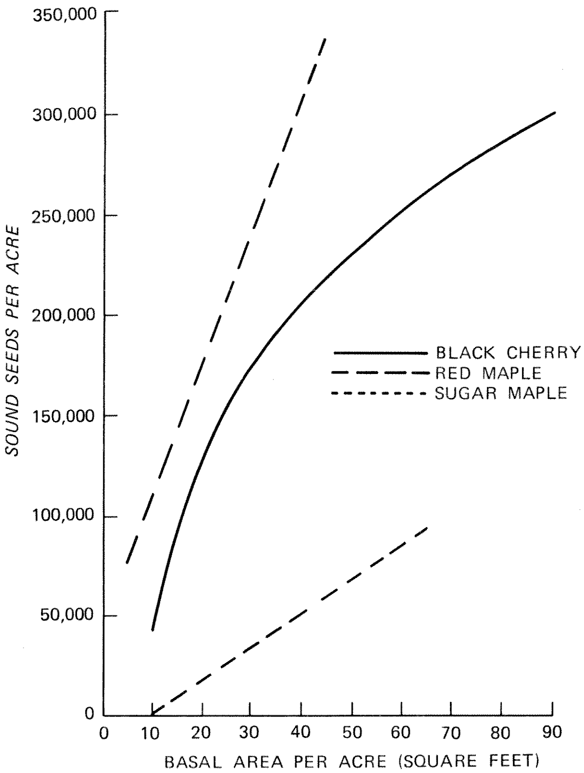
There was no statistically significant difference in seed soundness between the two areas, but it tended to be higher when seed production was high.

The percentage of sound sugar maple seed reported here agrees with similar data given by Carl and Yawney (1966). There appear to be no comparable data for either black cherry or red maple.

Seed production vs. basal area

The number and size of seed trees in a stand determine how much seed can be produced. To estimate the seed production that might be expected in different stands, I used regression analysis of the average sound seed production during the 1971 through 1976

Figure 3.—Average sound seed production per acre from 1971 through 1976. Regression formulas: Red maple $R^2 = .54$, $Y = 44890 + 6461.6\ X$; Black cherry $R^2 = .15$, $Y = -223980 + 268710 \log X$; Sugar maple $R^2 = .25$, $Y = -15176 + 1674.6\ X$.



period and the basal area per acre of trees in the 6-inch diameter class or larger. The 6-inch diameter limitation takes into account the influence of tree size on seed production. The regressions, plotted in Figure 3, are significant at the .10 level for black cherry and at the .05 level for the maples.

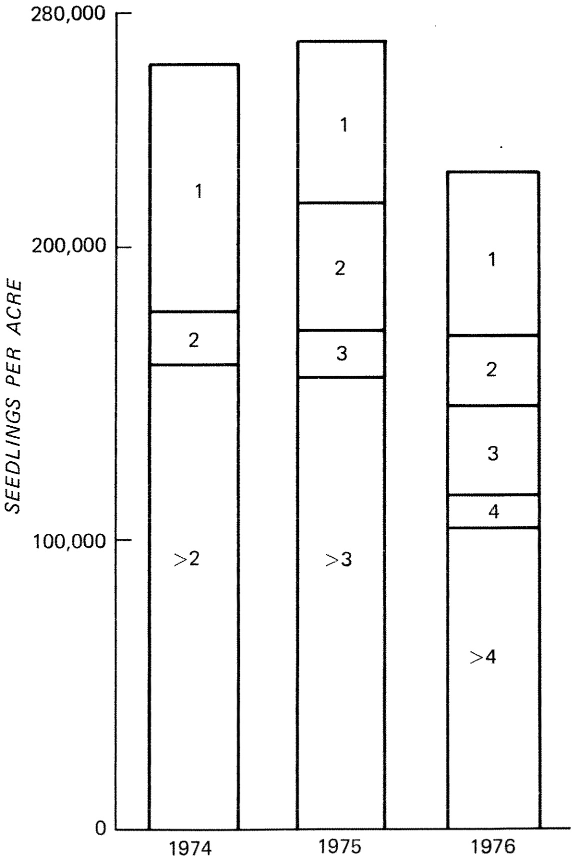
From these curves, it is evident that seed production and basal area are related for black cherry and red maple—an observation in agreement with Marquis and others (1975). Over the study period, red maple seed production increased faster with an increase in basal area than did black cherry or sugar maple. The curve for sugar maple emphasizes the low seed production of this species and suggests that this may be a major reason for its unsatisfactory regeneration.

Effect of seed production on regeneration

Large maple seed crops in one year are generally followed by a surge in maple regeneration the next year. Marquis (1975) also reports that red maple seed beneath a closed canopy lies dormant but viable through a full year. Occasionally, red maple and sugar maple seedlings may originate from a few seeds stored in the humus over a second winter. Some red maple seeds may germinate immediately after dispersal.

Black cherry responds differently. Even when little or no seed is produced, many new seedlings appear. These come from seeds stored in the humus and they mask the effect of the most recent seed crop on the current crop of new seedlings.

Figure 4.—Age-class distribution of black cherry seedlings, by year. The numbers indicate seedling age in years.



In general, the ratios of sound seed to new seedlings averaged about six to one for black cherry and red maple, and about five to one for sugar maple over the 1972 through 1976 period.

The effects of seed production on regeneration can be seen in the age-class distribution of seedlings, and the effects can be long lasting. A continued succession of good seed years means that all age classes are well represented. This situation prevails with black cherry (Fig. 4) more than with the maples.

When good seed years are periodic, then at least one age class is poorly represented. This is illustrated for red maple in Figure 5 and for sugar maple in Figure 6. A succession of inadequate seed crops can lead to poor species representation in the new stand.

Figure 5.—Age-class distribution of red maple seedlings, by year. The numbers indicate seedling age in years.

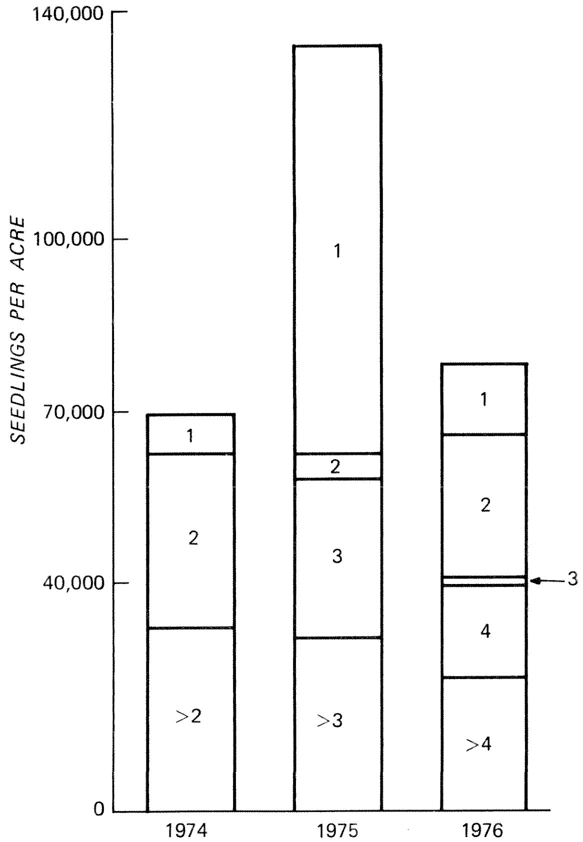
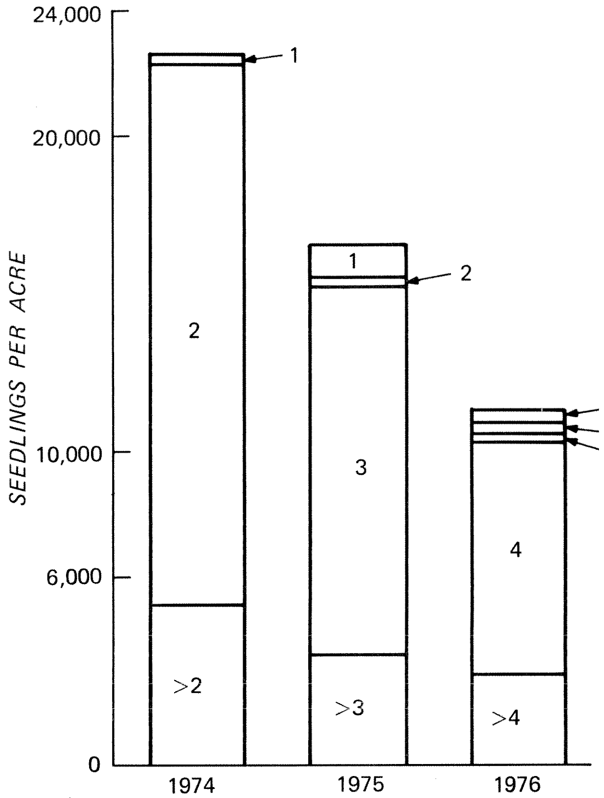


Figure 6.—Age-class distribution of sugar maple seedlings, by year. The numbers indicate seedling age in years.



Seed stored in the humus

Humus blocks cut in early spring and maintained in a greenhouse were used to estimate the amount of stored viable seed. The number of seeds varied by species and by year (Table 5). These data reflect the size of the seed crop the previous year.

The effect of stored seed is further illustrated by comparing the estimates of seed production to estimates of the number of new seedlings for selected years (Table 6).

For red maple, the very few new seedlings in 1974 point to the seed crop failure of 1973 and to the limited ability of these seeds to remain viable for more than 1 year. The same holds true for sugar maple.

Abundant black cherry regeneration appears almost every year. Even the poor seed crop of 1974 was followed by nearly as many seedlings the next year as was the large seed

Table 5.—Estimated number of sound seeds per acre stored in the humus, by species and year (thousands of seeds per acre)

Year	Red maple	Sugar maple	Black cherry
1973	313.4	94.4	319.4
1974	12.1	0.0	175.4
1975	263.8	0.0	139.2
1976	35.1	0.0	378.7

Table 6.—Estimated production of sound seeds and estimated number of seedlings in selected years

Species and year	Sound seeds per acre	Seedlings per acre
Red maple		
1972	652,400	—
1973	0	100,600
1974	432,300	6,900
1975	—	88,100
Sugar maple		
1972	254,900	—
1973	0	51,700
1974	—	200
Black cherry		
1973	426,100	—
1974	8,900	84,100
1975	—	61,000

crop of 1973. This could happen only if abundant seed was stored in a viable condition for 2 years or longer.

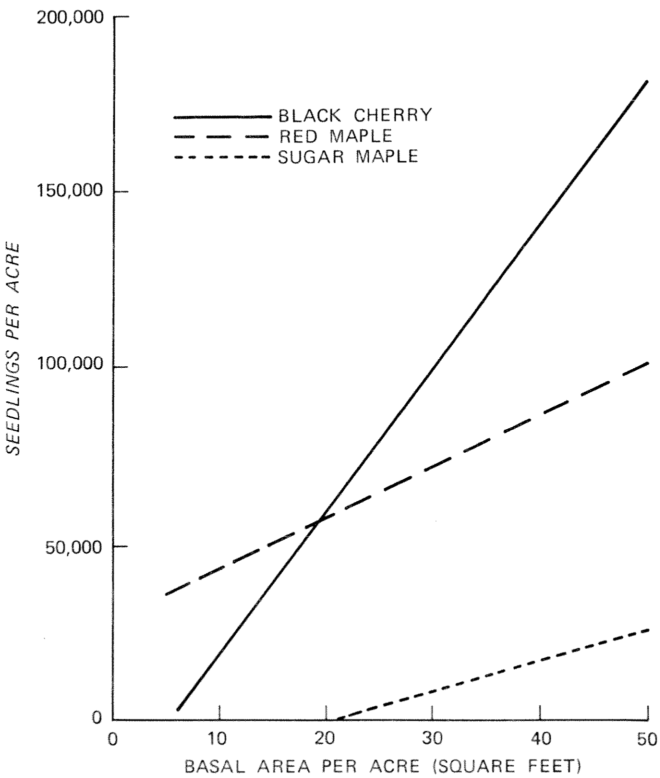
These inferences drawn from seed storage data are in agreement with observations reported by Marquis (1975) and Wendel (1977).

Effect of basal area on regeneration

To determine the relationship between advance regeneration and basal area, I used regression analysis of the average number of seedlings per acre (1974 through 1976) and the basal area per acre of black cherry, red maple, and sugar maple trees in the 6-inch diameter class or larger. The use of the average number of seedlings minimizes the effect of both bumper and failed seed crops.

Figure 7 illustrates the effect of basal area on the number of seedlings, which is best expressed as a straight-line relationship. However, there are important differences among species. For black cherry, the regression predicts a steep rise in the number of seedlings as the basal area increases. Both red and sugar maple make more moderate increases in the number of seedlings as their basal area increases. However, with the same basal area, red maple seedlings are much more abundant than sugar maple seedlings.

Figure 7.—The effect of basal area on number of seedlings. Regression formulas: Black cherry R^2 = .58, Y = −22008 + 4089 X; Red maple R^2 = .58, Y = 29581 + 1432.6 X; Sugar maple R^2 = .64, Y = −18668 + 897.05 X.



USE

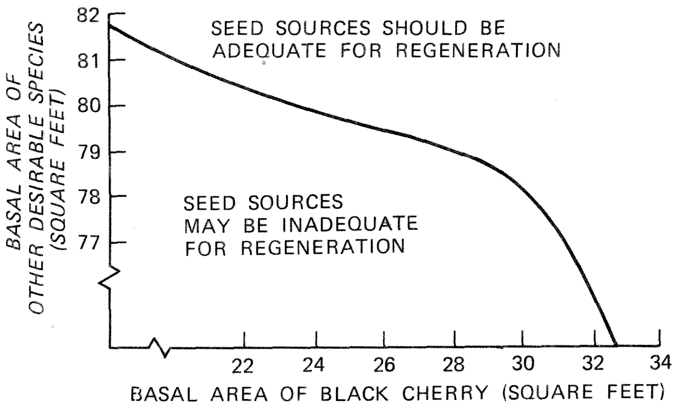
The relationship between advance regeneration and basal area can be helpful in judging the potential regenerative capacity of Allegheny hardwood stands. To further define this relationship, data reported here were supplemented with data from other regeneration studies on the Allegheny Plateau. In total, data from 42 stands were used.

The first step was to develop two regressions of the number of seedlings per acre as a function of basal area per acre. One regression was for black cherry only, the other was for the other desirable species—red maple, sugar maple, white ash, yellow-poplar, cucumbertree, and red oak. This species breakdown is required because of the impact that black cherry has on the regeneration of new stands and because its regeneration characteristics differ from those of the other desirable species. Basal area estimates were based on trees of these species 6 inches or larger in dbh.

Regeneration surveys of these 42 stands were made with the techniques described by Marquis and others (1975). Briefly, regeneration plots were classed as stocked or not stocked according to the number of black cherry seedlings and seedlings of other desirable species present. If at least 70 percent of the plots were stocked, the stand was classed as stocked. For this study, the minimum number of seedlings per plot required by the regeneration guide (Marquis and others 1975) was increased to 25 black cherry, or to any combination of black cherry and other desirable species numbering at least 100 seedlings. These increases were based on the results of field trials, and they provide a more accurate appraisal of regeneration potential.

With these advance stocking criteria, additional regressions were run that related the total number of seedlings per acre (for black cherry alone and for other desirable species as a group) to the proportion of plots with satisfactory stocking. The number of seedlings per acre required for various stocking levels were then estimated from these regressions. These values were then substituted into the first regressions to estimate the amount of overstory basal area required in each species group to obtain a given level of advance regeneration. These estimates were made for various combinations of the two species groups (e.g., 60 percent stocked with black cherry alone plus 10 percent stocked with any desirable species to total 70 percent stocked), and these values were plotted to determine seed source adequacy (Fig. 8).

Figure 8.—The intersection of the lines drawn from the basal area of black cherry and from the basal area of the other desirable species indicates the adequacy of seed sources.



To use this figure for any Allegheny hardwood stand, first determine the basal area of black cherry and of the other desirable species in the 6-inch diameter class or larger. Plot these values. If they intersect within the adequate seed source area—for example, 30 ft^2 of black cherry and 79 ft^2 of other desirable species—the assumption can be made that this stand has the potential to regenerate successfully. It does not mean that adequate advance regeneration is a certainty now or in the future. When an inadequate seed source is indicated, as for a stand with 28 ft^2 of black cherry and 78 ft^2 of other desirable species, sufficient advance regeneration is unlikely to develop. In this situation, it may be necessary to carry the stand through an extended period of thinning to develop desired species to seed-bearing size, to consider seeding or planting to augment natural regeneration, or to consider protecting seedlings from browsing by deer.

SUMMARY

The results of this study indicate that:

1. Flower crops are more reliable predictors of size of seed crop for red maple and sugar maple than for black cherry, but frequent checks must be made to detect and evaluate losses due to adverse weather, insects, or diseases.
2. Large seed crops may be expected 1 year out of 2 for black cherry, 1 year out of 3 for red maple, and 1 year out of 6 for sugar maple.
3. Seed dispersal varies from year to year but, in general, the red maple crop falls in June, black cherry in August and September, and sugar maple in October.
4. Seed soundness—the potential to germinate—tends to be higher when seed production is high. Over the study period, seed soundness averaged 91 percent for black cherry, 82 percent for red maple, 56 percent for sugar maple.
5. Most black cherry seeds do not germinate in the spring following dispersal. Such seeds remain viable in the humus for up to 3 years and are an important resource when cherry crops fail. On the other hand, few red maple and sugar maple seeds remain viable over two winters. Because of this, maple regeneration depends on the current seed crop.
6. Both seed production and advance regeneration are related to basal area. In general, a stand will be adequately stocked with black cherry regeneration if there is about 33 ft^2 of black cherry in trees 6 inches in dbh or larger. For a stand to be adequately stocked with the other desirable species, there must be about 82 ft^2 of these species in trees 6 inches in dbh or larger. These values are appropriate only on the Allegheny Plateau where large numbers of seedlings are needed to offset losses caused by deer browsing.
7. A simple method to judge the potential regenerative capacity of an Allegheny hardwood stand, based on the estimated basal areas of black cherry and of the other desirable species, has been developed.

LITERATURE CITED

Carl, Clayton M., Jr., and Harry W. Yawney.
1966. **Four stratification media equally effective in conditioning sugar maple seed for germination.** Tree Plant. Notes 77:24-28.

Godman, Richard M., and Gilbert A. Mattson.
1976. **Seed crops and regeneration problems of 19 species in northeastern Wisconsin.** U.S. Dep. Agric. For. Serv. Res. Pap. NC-123.

Grisez, Ted J.
1975. **Flowering and seed production in seven hardwood species.** U.S. Dep. Agric. For. Serv. Res. Pap. NE-315.

Hough, A. F.
1935. **Crown spread of Allegheny hardwoods.** U.S. Dep. Agric. For. Serv., Allegheny For. Exp. Stn. Tech. Note 7.

Marquis, David A.
1975. **Seed storage and germination under northern hardwood forests.** Can. J. For. Res. 5:478-484.

Marquis, David A., Ted J. Grisez, John C. Bjorkbom, and Benjamin A. Roach.
1975. **Interim guide to regeneration of Allegheny hardwoods.** U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. NE-19.

U.S. Forest Service.
1974. **Seeds of woody plants in the United States.** U.S. Dep. Agric. For. Serv., Agric. Handb. 450. Washington, D.C.

Wendel, G. A.
1977. **Longevity of black cherry, wild grape, and sassafras seed in the forest floor.** U.S. Dep. Agric. For. Serv. Res. Pap. NE-375.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1979—603-011/11

Common and scientific names of trees referred to in this report:

Ash, white	*Fraxinus americana* L.
Beech	*Fagus grandifolia* Ehrh.
Cherry, black	*Prunus serotina* Ehrh.
Cucumbertree	*Magnolia acuminata* L.
Maple, red	*Acer rubrum* L.
Maple, sugar	*Acer saccharum* Marsh.
Oak, northern red	*Quercus rubra* L.
Yellow-poplar	*Liriodendron tulipifera* L.

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

- Beltsville, Maryland.
- 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.
- Kingston, Pennsylvania.
- 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.
- Warren, Pennsylvania.