United States
Department of
Agriculture

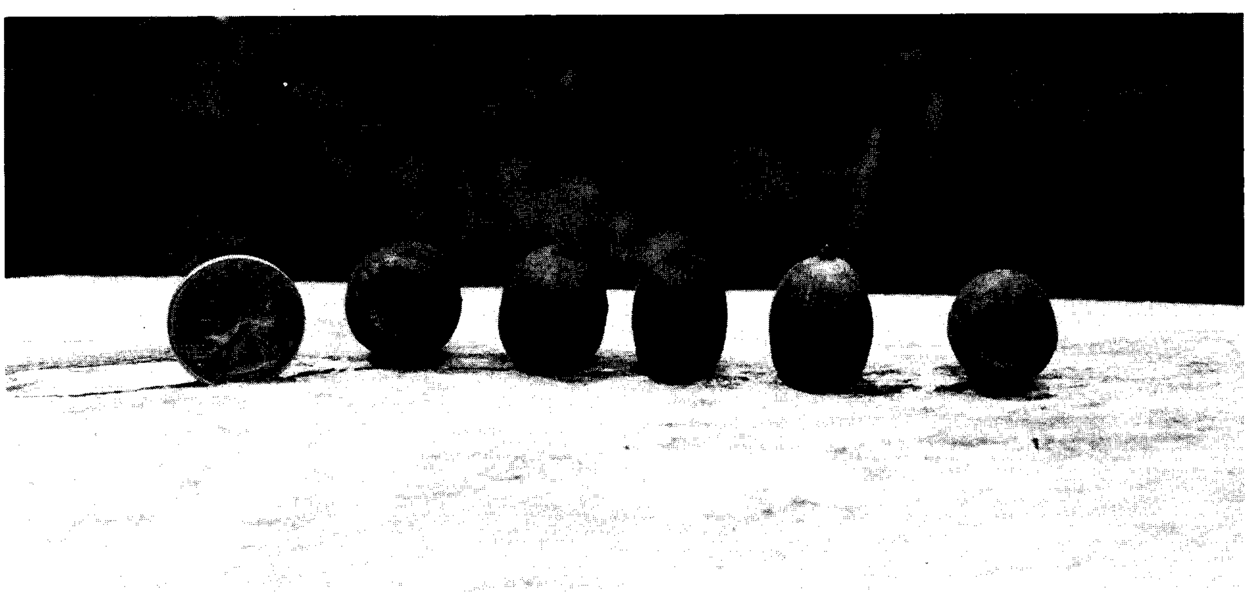
Forest Service

**Northeastern Forest
Experiment Station**

Research Paper NE-680

Acorn Production in Northern Red Oak Stands in Northwestern Pennsylvania

L. R. Auchmoody
H. Clay Smith
Russell S. Walters



Abstract

Northern red oak acorn production was measured in 21 maturing stands on good sites in northwestern Pennsylvania. The number of acorns produced per acre varied from a low of 7,000 in a poor seed year to nearly 273,000 in a bumper year. Some acorns were produced in all years. In no year was there consistently good acorn production at all areas, nor was there a good crop for more than 2 consecutive years at any location. Acorn production was not related to the mean diameter and range of basal area of red oak trees in the experimental stands. Freezing temperatures when oaks were in flower was a major factor affecting acorn production on the Allegheny Plateau.

The Authors

L. R. AUCHMOODY is a research forester and principal soil scientist at the Northeastern Forest Experiment Station's Forestry Sciences Laboratory, Warren, Pennsylvania. He holds B.S. and M.S. degrees from the State University of New York College of Forestry, and a Ph.D. from North Carolina State University at Raleigh. He conducts research on site evaluation, forest nutrition, and regeneration of oaks and Allegheny hardwoods.

H. CLAY SMITH is project leader and principal silviculturist at the Northeastern Forest Experiment Station's Timber and Watershed Laboratory, Parsons, West Virginia. He received his B.S. and M.S. degrees from West Virginia and Purdue Universities, and joined the Northeastern Forest Experiment Station in 1962. He has conducted extensive silvicultural research in Vermont and West Virginia.

RUSSELL S. WALTERS is principal silviculturist and research forester at the Northeastern Forest Experiment Station's Forestry Sciences Laboratory, Warren, Pennsylvania. He holds a B.S. from Michigan State University, an M.S. from Oregon State University, and a Ph.D. from the State University of New York College of Forestry. He conducts research on silviculture and regeneration of oaks and Allegheny hardwoods.

Acknowledgment

The authors wish to thank Jimmy Galford, research entomologist, U.S. Department of Agriculture, Forest Service, (retired) and Perry Fox, forestry technician, U.S. Department of Agriculture, Forest Service, for collecting the acorn cap data used in this study. Study areas on the Moshannon State Forest were made available by the Pennsylvania Bureau of Forestry and the Allegheny National Forest by the U.S. Department of Agriculture, Forest Service. Additional support also was provided by Paul Augustine, Ed Richards, and Lee Warren of the Moshannon State Forest.

Manuscript received for publication 7 June 1993

USDA FOREST SERVICE
5 RADNOR CORP CTR STE 200
PO BOX 6775
RADNOR PA 19087-8775

December 1993

Introduction

Production of northern red oak (*Quercus rubra* L.) acorns is essential for establishing abundant advanced red oak regeneration. Acorns also are an important food supply for deer, squirrels, turkeys, and many other wildlife species. Therefore, estimates of acorn crop size, periodicity of acorn crops, and knowledge of the variables that can affect acorn production are important to forest and wildlife managers alike.

Reproduction of northern red oak after cutting comes from advanced seedlings, seedling sprouts, and stump sprouts. In northwestern Pennsylvania, however, few advanced red oak seedlings occur in mature red oak stands on good sites. While predation of acorns and young seedlings by deer, insects, and small mammals contribute to the lack of advanced seedlings, poor acorn crops also are a significant limitation for advanced regeneration.

In 1988 the Northeastern Forest Experiment Station began studying the limitations for red oak seedling establishment in northwestern Pennsylvania. One of the studied limitations was acorn production. Reported in this paper is northern red oak acorn production and flowering observations during 4 years in one research area, and 2 years at a second area. Also reported are relationships between acorn production and red oak stand basal area and red oak stand diameter.

Study Areas

Study installations are located on the Moshannon State Forest and the Allegheny National Forest within the unglaciated section of the Allegheny Plateau in northwestern Pennsylvania. At the Moshannon installation, there were three study areas where acorn production was measured, and on the Allegheny National Forest there were four areas. Each study area consisted of three 4-acre stands (12 acres total) fenced to exclude deer.

Each 12-acre area was characterized by uniform, gently-rolling topography. Elevations among the areas ranged from about 1,500 to 2,300 feet, though all but one were above 1,700 feet (Table 1). The regional climate is cool and moist, with precipitation averaging nearly 4 inches per month during the growing season. The growing season length is approximately 130 days, with an average air temperature of 60°F. Late spring freezes are common through early June, particularly above 1,700 feet, and are known to be a critical factor for acorn production in some years (Grisez 1975). Because of ample rainfall, cool summer temperatures, and much cloud cover, soil moisture usually remains plentiful until late in the growing season. Snow cover prevails from December through mid-March.

Soils vary somewhat among the areas, but none of the sites has any important physical soil limitations for red oak development or acorn production. Soil texture ranges from sandy loam to silty clay loam, and the effective soil depth varies from approximately 24 to 30 inches. Humus types are duff mulls.

Each of the experimental stands, except for Keller Road (Table 1), originated after clearcutting, and is even aged and dominated by northern red oak in the overstory. The Keller Road site is uneven aged and has less red oak than the other sites, although the red oak trees there are larger and older. Site index for red oak at age 50 varied from 63 to 79 among the seven areas. Common associated species in the study areas were white oak (*Quercus alba* L.), black oak (*Quercus velutina* Lam.), chestnut oak (*Quercus prinus* L.), red maple (*Acer rubrum* L.), sugar maple (*Acer saccharum* Marsh.), American beech (*Fagus grandifolia* Ehrh.), black cherry (*Prunus serotina* Ehrh.), white ash (*Fraxinus americana* L.), and cucumbertree (*Magnolia acuminata* L.).

Table 1. — Description of the areas where northern red oak production was measured. Each study area includes three 4-acre stands, for a total of 12 acres

Study area	Elevation (ft)	Site index	Soil series	Red oak stand age	Red oak basal area[a]	Red oak diameter[a]	Even aged
			---------- Moshannon State Forest ----------				
Smith Road	2,300	63	Hazleton/Cookport	82	70.5	14.1	Yes
Gordon Road	1,850	75	Rayne/Gilpin	82	75.9	20.3	Yes
Snotrail	1,700	73	Wharton/Gilpin	78	73.4	17.6	Yes
			---------- Allegheny National Forest ----------				
Route 337	1,860	74	Hazleton/Cookport	76	54.4	16.3	Yes
Keller Road	1,530	75	Cavode	109	24.7	22.2	No
Buehler Corners	1,720	79	Hazleton/Cookport	72	78.2	16.8	Yes
Whistletown	1,750	79	Hazleton/Cookport	76	97.5	15.3	Yes

[a] For trees 1.0 inches d.b.h. and larger.

Methods

The basic plot design was the same for each of the study areas. At the Moshannon State Forest, acorn production was estimated annually at three areas over a 4-year period, and annually on the Allegheny National Forest at four areas for a 2-year period. At each area, acorn production was measured in three 4-acre stands providing estimates from a total of 84 acres. One stand at each area was uncut, one had its overstory density reduced to 60 percent relative density, and one had its overstory density reduced to 40 percent relative density. Cutting procedures in the 60- and 40-percent stands retained all of the northern red oaks large enough to produce acorns, so there was minimal effect from the cutting treatments on the potential of the different stands to supply acorns. All measurement sites initially were located in uniform, fully-stocked stands before cutting, and all were fenced to exclude deer.

Acorn production was estimated indirectly from acorn cap counts taken in each 4-acre stand, as recommended by Shaw (1974). Cap counts for acorns that matured in the previous fall were completed by the following June after all caps had fallen and before starting to decompose. The sampling procedure used to estimate the 1988 acorn crop consisted of randomly selecting 10 large red oaks in each 4-acre stand, then counting the acorn caps on four 1-square-foot plots beneath each tree. Trees were selected without previous knowledge of their acorn production. Thus, in each 4-acre stand there were 40 acorn cap plots for a total of 120 plots per area. In the following years, acorn cap counts were conducted on 30 systematically located, 1-foot-square plots in each 4-acre stand, for a total of 90 plots per area.

Results

Northern Red Oak Acorn Production

The number of northern red oak acorns produced annually over a 4-year period at the Moshannon sites and over a 2-year period at the Allegheny National Forest sites are given in Table 2. Some acorns were produced each year at all of the areas, but there was great variation from area to area within the same year, and among study areas in different years. Production varied from a low of about 7,000 acorns at the Whistletown area in 1990 to a high of nearly 273,000 in the same year at Smith Road (Table 2). In no year was there consistently good production (>125 M acorns/acre) at all areas, nor was there a good crop for more than two consecutive years at any location. Acorn production in 1991 was uniformly poor, the result of a wide-spread hard freeze in 1990 when oaks were in flower.

Acorn Production and Stand Parameters

Relationships between annual acorn production and mean residual red oak stand diameter and red oak stand basal area were examined using multiple regression analyses. Data were from 9 stands on the Moshannon State Forest and 12 stands on the Allegheny National Forest.

Analyses using all 21 sites showed no regional relationships between acorn production and stand diameter (mean red oak diameter) or between acorn production and the quantity of red oak present in the stands (red oak stand basal area) in either 1990 or 1991, the two years data were available for all sites. Instead, 1990 acorn production was strongly site related, with two areas having good or bumper crops and most of the remaining sites having poor crops regardless of tree size or the quantity of red oak present. In 1991, a uniformly poor year for acorn production region-wide, only one site produced more than 80 M acorns per acre, and there was no relationship between acorn production and stand parameters on the other sites.

Regression analyses of acorn production on the Moshannon State Forest also showed that acorn production was strongly site related, and not related to either red oak tree size or basal area in the individual stands. The relationships between acorn production and mean red oak stand diameter over the 4-year period are shown in Figure 1. Although a positive relationship between acorn production and red oak

Table 2.—Number of acorns per acre produced at seven areas in northwestern Pennsylvania

Study area	1988	1989	1990	1991
		---------- Moshannon State Forest ----------		
Smith Road	49,368 (6,142)[a]	133,584 (14,253)	272,979 (18,182)	22,748 (6,502)
Gordon Road	127,776 (11,805)	143,458 (16,754)	69,212 (7,815)	22,264 (3,658)
Snotrail	135,036 (12,763)	38,188 (7,597)	45,012 (7,740)	30,976 (4,927)
		---------- Allegheny National Forest ----------		
Route 337	---	---	128,744 (16,023)	53,240 (9,280)
Keller Road	---	---	16,456 (3,240)	49,368 (8,323)
Buehler Corners	---	---	20,812 (3,525)	49,368 (6,645)
Whistletown	---	---	6,776 (2,567)	81,312 (8,793)

[a] Standard error of mean in parentheses.

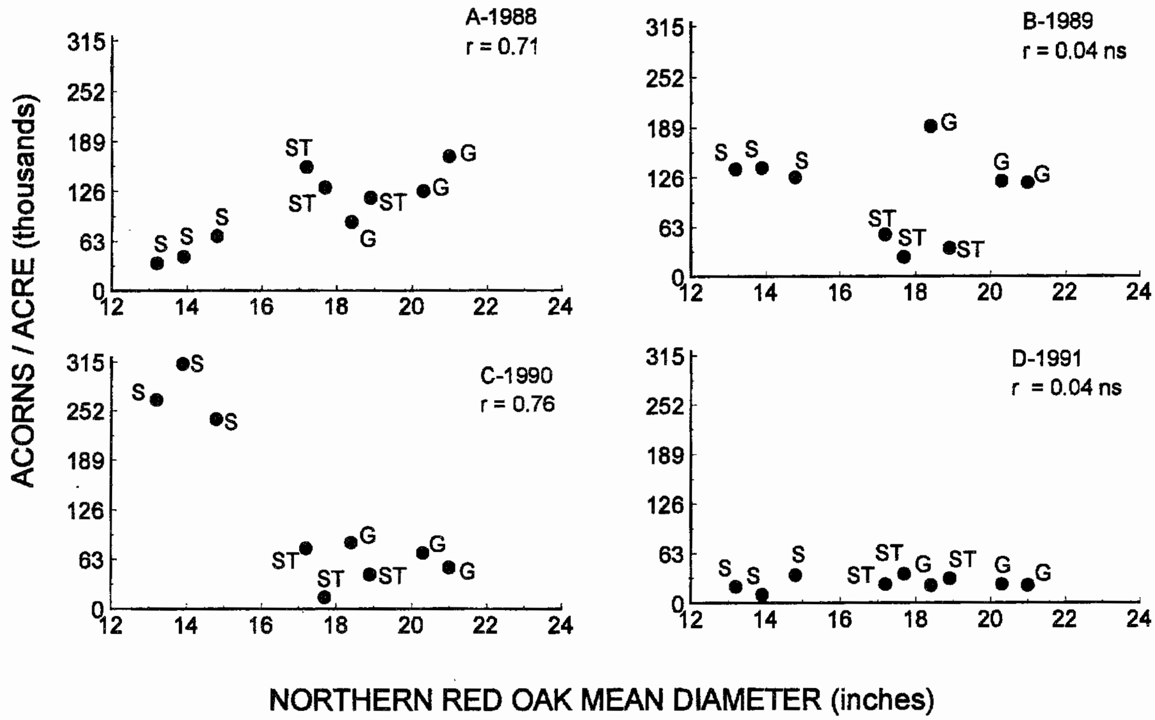


Figure 1.—Northern red oak acorn production and the average stand diameter of red oak during 4 years on the Moshannon State Forest. Points with the same symbol are from the same study area (S = Smith Road, G = Gordon Road, ST = Snotrail). Acorn production was related to location, not directly to stand diameter.

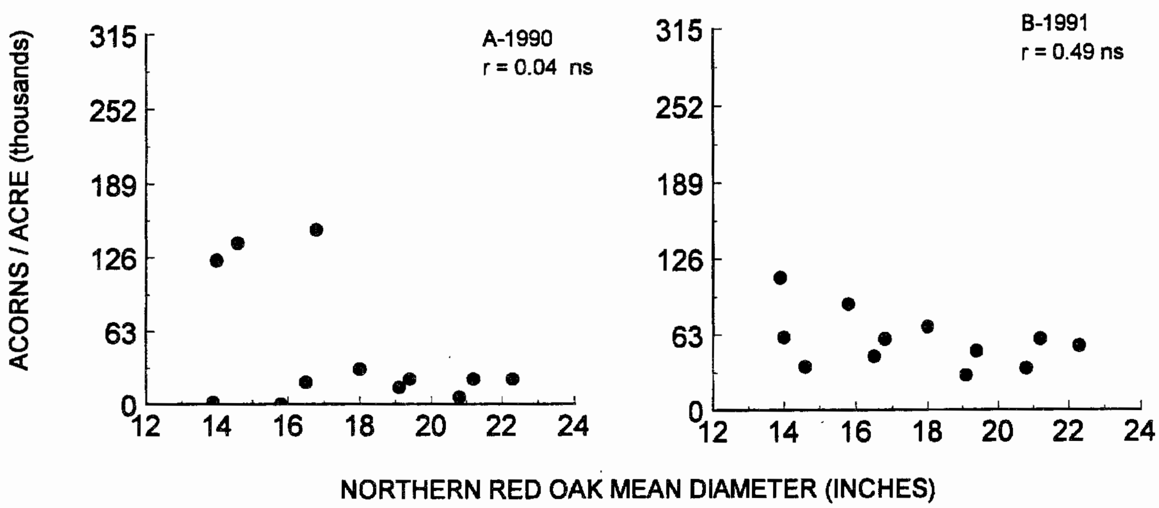


Figure 2.—Northern red oak acorn production and the average stand diameter of red oak during a 2-year period on the Allegheny National Forest. Acorn production was related to location, not directly to stand diameter.

diameter is suggested in 1988 (Fig. 1) and a negative relationship is suggested in 1990, these are caused by differences in acorn production among the areas, and not from differences in stand diameters. For example, the Smith Road stands (Fig. 1) had the smallest mean red oak diameters, yet in 1990, those stands had the largest acorn crop and in 1988, the poorest. No relationships between acorn production and stand diameter were indicated for 1989 or 1991 (Fig. 1). Further evaluation also showed that acorn production in stands from within a given area were similar and that no consistent relationship was found between acorn production and red oak stand diameter during the 4-year period at any of the three areas.

The relationships between acorn production and stand parameters on the Allegheny National Forest were similar to those on the Moshannon State Forest (Fig. 2). In 1990 one area had a good acorn crop and the remaining three areas were poor, regardless of their diameter or the quantity of red oak basal area in the stands. In 1991, two of the study stands at the Whistletown site had fair crops, while all other sites had poor crops regardless of stand parameters.

Flower Production

Observations of red oak flowering were made annually at each of the seven areas, though no quantitative data were actually collected. Abundant male flowers (catkins) with some year-to-year variation were observed in each of the 4 years, suggesting that male flower production is not a limiting factor for acorn production. Female flowers also were present each year on fallen branches; however, these limited observations were not adequate to assess year-to-year variation. In 3 of the 5 observation years, spring freezes destroyed most of the flower crops at most study areas (1988, 1990, 1992).

Acorn Crop Ratings

During the 4-year measurement period, acorn crops from the 21 study stands varied from zero to more than 312,000 acorns per acre. From subjective ratings of acorn abundance and the estimated number of acorns present from cap counts in the same stands, a simple acorn crop rating guide was developed (Table 3).

Quick estimates of the acorn crop rating and actual acorn numbers can be made from estimates of the number of acorns or the acorn caps per square foot. At least 30 square-foot samples are recommended. With a little experience, the number of acorns per square foot can be estimated at a glance near the termination of peak acorn fall, but plots are required for cap counts since the caps become embedded in the litter and are difficult to see. If acorn estimates are made where deer and small mammal populations are high, some acorns will be consumed quickly or cached, causing subsequent low estimates of the total crop. In theses cases it is best to use the acorn cap technique after all caps have fallen to the ground, since cap numbers are much less affected by wildlife consumption.

Table 3.—Guide for rating northern red oak acorn crops

Subjective crop rating	Actual acorns/acre	Approximate acorns / ft^2
Bumper	>250,000	5 +
Good	125 - 250,000	3 - 5
Fair	65 - 125,000	1.5 - 3
Poor	20 - 65,000	0.5 - 1.5
Trace to none	<20,000	0 - 1.5

Discussion

Acorn production estimates are important for their value in wildlife management and as a means for establishing oak reproduction. Trapping and ground counting of acorns are the methods commonly used to estimate acorn production. The accuracy of these techniques, though, can be affected by the uneven dispersal pattern that requires a prohibited large number of traps, and also by consumption of acorns by deer, small mammals, and birds during the dispersal period. For example, it rarely is possible with traps to sample adequately the uneven distribution of acorns, which, because of their weight, remain concentrated beneath mother trees. Acorns caught in traps also are subject to significant pilferage by predators. Ground surveys, as well, are subject to serious underestimates because predators rapidly consume acorns throughout the dispersal period.

The cap counting technique offers a way to minimize these problems. It allows use of a large number of inexpensive temporary plots to sample thoroughly uneven acorn distributions, and because acorn caps are not eaten by small mammals, primarily avoids underestimates from predator consumption. Additionally, cap counts can be conducted over a much longer period and are not restricted to a short interval at dispersal.

Estimates of northern red oak acorn production at the seven areas varied from approximately 7,000 to nearly 273,000 acorns per acre during the measurement period. These values encompass the range of red oak acorn production reported in the literature, but substantially exceed the reported values where exceptionally good or bumper crops occurred. In comparison to our estimates, Gysel (1957) reported 30,600 northern red oak acorns per acre as the 4-year average for good sites in Michigan. In the southern Appalachians, Beck and Olson (1968) measured 6,600 to 94,600 acorns per acre for several species of oaks. In a review of acorn production, McQuilken (1983) concluded that annual acorn crops ranged from none in poor years to more than 100,000 in good years. Barni (1980) reported annual averages of 31,074; 11,164; and 40,199 acorns per acre in north central Pennsylvania from 1977 to 1979, respectively. We feel that our higher estimates may be due not only to the inclusion of exceptionally good crop years during the measurement period, but also to estimates made from acorn cap counts in stands where deer were excluded, resulting in estimates unaffected by predator consumption.

We experienced much variation in acorn production among the different sites and from year to year, regardless of the diameter or quantity of red oak in the stands. This variation agrees with a common conclusion drawn from the literature that acorn crops are sporadic, infrequent, and unpredictable (Sharp and Chisman 1961; Watt 1979; McQuilken 1983).

The reasons for this variation are not known, though there have been many attempts to determine the causes. In the present study, all of the stands were above the minimum seed-bearing size and age, and all were well stocked with red oak. Thus, in this study, tree age and size and stocking of red oak should not have been important factors limiting acorn production. In addition, we know good production of male flowers occurred annually and that female flowers were present each year as well. Nor did cyclic flower production due to physiological reasons appear to be the major cause of the variation.

Weather related limitations for acorn production, particularly freezing temperatures when oaks are in flower, appear to be one of the most critical factors for acorn crops on the Allegheny Plateau. Oak flowers were affected by spring freezes in 3 of the 5 years that flowering was observed. Not all of the sites were affected each year, suggesting that small differences in elevation or the location of areas on the plateau may allow some areas to remain unaffected. Our observations agree with Goodrum et al. (1971) that low spring temperatures kill oak flowers and may have an overall limiting effect on acorn production. Dry, desiccating winds during pollen dispersal combined with low temperatures during flowering also may adversely affect acorn production (Sharp and Chisman 1961). Conversely, good crops result when relatively wet periods are followed by warmer temperatures at the beginning of the flowering period.

Finally, the study results suggest that stands with a northern red oak mean diameter of at least 14 inches and basal area of 70 square feet are above the threshold size for good acorn production, and are fully capable of producing bumper acorn crops. Nearly 273,000 acorns per acre were produced by stands with these minimum parameters in 1990, for example. Downs and McQuilken (1944) in the Piedmont of Georgia and in the Smokey Mountains of North Carolina found that the desirable diameter for optimum red oak acorn production was from 12 to 21 inches. In Michigan, Gysel (1956) determined that acorn production of northern red oak dropped rapidly below 14 inches d.b.h. Thus, it seems that acorn production in northern red oak stands with a mean diameter of 14 inches and larger should not be influenced greatly by increasing stand diameter.

Throughout the literature, terms like "bumper," "good," and "poor" have been used to characterize the acorn seed crop. We provided a general guide for red oak seed crops as related to acorn production per acre. Also, we related acorn production to the amount of acorns (or caps) observed on a square foot. This approach should result in more consistent use of terminology and less subjectivity among forest managers.

Literature Cited

Barni, Robert T. 1980. **Production and utilization of acorns on the Quehanna Wild Area.** University Park, PA: The Pennsylvania State University, School of Forest Resources. 48 p. M.S. thesis.

Beck, Donald E.; Olson, David F., Jr. 1968. **Seed production in southern Appalachian oak stands.** Res. Note SE-91. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 7 p.

Downs, Albert A.; McQuilken, William E. 1944. **Seed production of southern Appalachian oaks.** Journal of Forestry. 42: 913-920.

Goodrum, P. D.; Reid, V. H.; Boyd, C. E. 1971. **Acorn yields, characteristics, and management criteria of oaks for wildlife.** Journal of Wildlife Management. 35(3): 520-531.

Grisez, Ted J. 1975. **Flowering and seed production in seven hardwood species.** Res. Pap. NE-315. Upper Darby, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 8 p.

Gysel, Leslie W. 1956. **Acorn production on good, medium, and poor oak sites in southern Michigan.** Journal of Forestry. 55: 570-574.

McQuilken, Robert A. 1983. **Silvical factors affecting the regeneration of oaks and associated species in Pennsylvania.** In: Finley, James; Cochran, Roe S.; Grace, James R., eds. Proceedings, Regenerating Hardwood Stands: 1983 Penn State Forestry Issues Conference; 1983 March 15-16; University Park, PA. University Park, PA: The Pennsylvania State University: 37-56.

Sharp, W. M.; Chisman, H. H. 1961. **Flowering and fruiting in the white oaks; I. Staminate flowering through pollen dispersal.** Ecology. 42(2): 365-372.

Shaw, M. W. 1974. **The reproductive characteristics of oak.** In: Morris, M. G.; Perrin, F. H., eds. The British oak: Its history and natural history. Published for the Botanical Society of the British Isles by E. W. Classey, Hampton, England: 162-181.

Watt, R. F. 1979. **The need for adequate advance regeneration in oak stands.** In: Holt, H.A.; Fischer, B. C., eds. Regenerating Oaks in Upland Hardwood Forests. Proceedings of a symposium; 1979 February 22-23; West Lafayette, IN. West Lafayette, IN: Purdue Research Foundation: 11-17.

Printed on Recycled Paper

☆U. S. GOVERNMENT PRINTING OFFICE: 1993-750-123/80002

Auchmoody, L. R.; Smith, H. Clay; Walters, Russell S. 1993. **Acorn production in northern red oak stands in northwestern Pennsylvania.** Res. Pap. NE-680. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 5 p.

Northern red oak acorn production was measured in 21 maturing stands on good sites in northwestern Pennsylvania. The number of acorns produced per acre varied from a low of 7,000 to nearly 273,000. Acorns were produced in all years. In no year was there consistently good acorn production at all areas, nor was there a good crop for more than two consecutive years at any location. Freezing temperatures when oaks were in flower was a major factor affecting acorn production on the Allegheny Plateau.

ODC 232.311 : 176.1

Keywords: acorn production, stand parameters, flowering, freezing, cap counts, acorn crop guide

Headquarters of the Northeastern Forest Experiment Station is in Radnor, Pennsylvania. Field laboratories are maintained at:

Amherst, Massachusetts, in cooperation with the University of Massachusetts

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

Orono, Maine, in cooperation with the University of Maine

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

University Park, Pennsylvania, in cooperation with The Pennsylvania State University

Warren, Pennsylvania

"Caring for the Land and Serving People Through Research"

REMEMBER...
Smokey Has
for Fifty Years
Prevent Forest Fires