Acorn Weevils, Rodents, and Deer All Contribute to Oak-Regeneration Difficulties in Pennsylvania

by David A. Marquis
Philip L. Eckert
Benjamin A. Roach

USDA FOREST SERVICE RESEARCH PAPER NE-356
1976

NORTHEASTERN FOREST EXPERIMENT STATION
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
6816 MARKET STREET, UPPER DARBY, PA. 19082

The Authors

DAVID A. MARQUIS received his bachelor of science degree in forestry from the Pennsylvania State University in 1955 and his master's and doctoral degrees in forest ecology and silviculture from Yale University in 1963 and 1973 respectively. He joined the Northeastern Forest Experiment Station's silviculture research unit in New Hampshire in 1957, where he studied problems of regeneration and thinning in northern hardwoods. Between 1965 and 1970 he served on the timber- and watershed-management research staff at the Station's headquarters in Upper Darby, Pa. Since 1970, Dr. Marquis has been project leader of the silviculture research unit at Warren, Pa., where he heads a program of research on problems related to the regeneration and culture of high-value hardwoods on the northern Allegheny Plateau.

PHILIP ECKERT received his bachelor's degree from the Pennsylvania State University in 1954. Employed by the Pennsylvania Department of Environmental Resources at the Mont Alto Nursery from 1955 to 1956, he has since served as Management Forester at the Michaux State Forest and is presently serving at the Tuscarora State Forest.

BENJAMIN A. ROACH, research forester, conducted research in oak silviculture and management, initially with the Central States Forest Experiment Station and later with the Northeastern Forest Experiment Station. He served in administrative positions in Upper Darby, Pa., and in Washington, D. C., and is now stationed at the Forestry Sciences Laboratory in Warren, Pa. where he is conducting research in the growth and management of black cherry and associated species.

MANUSCRIPT RECEIVED FOR PUBLICATION 16 AUGUST 1976.

Acorn Weevils, Rodents, and Deer All Contribute to Oak-Regeneration Difficulties in Pennsylvania

ABSTRACT

In parts of Pennsylvania, oak regeneration after harvest cutting or natural disturbances has been very poor. Studies on the Tuscarora State Forest suggest that the primary cause of natural regeneration failure may be a lack of viable acorns; on some sites acorn insects and rodents destroy nearly all acorns, even in good seed years. Artificial regeneration is not without difficulties either: rodents were able to reach direct-seeded acorns even through plastic protectors; and planted seedlings have been severely damaged by deer browsing.

KEYWORDS: Oak trees, regeneration, damage by insects, damage by rodents; damage by deer.

OAK REGENERATION after cutting comes mainly from advance seedlings, which are usually present in adequate numbers beneath mature stands over much of the oak range *(Sander and Clark 1971)*. But in parts of Pennsylvania, oak advance seedlings are extremely scarce, and regeneration after harvest cutting or natural disturbances has been very poor. The problem has assumed major significance during the past few years because of severe defoliation by the gypsy moth, oak leaf roller, and other insects, which has left hundreds of thousands of acres with dead overstory trees and little or no regeneration to replace them *(Nichols 1973)*.

Attempts to stimulate the development of additional advance regeneration through shelterwood cuttings have been unsuccessful in these problem areas; so have attempts to plant oak seedlings. Browsing by the unusually large deer herd in Pennsylvania, inadequate acorn crops, destruction of acorns by insects, and consumption of acorns by rodents have all been suggested as possible causes of the regeneration difficulties.

To determine the relative importance of each of these factors, studies were made in central Pennsylvania by the Northeastern Forest Experiment Station and the Pennsylvania Bureau of Forestry in 1973-75. These studies have shown that acorn insects, rodents, and deer all have significant effects, and that, in attempts to secure oak regeneration in this region by either natural or artificial means, all three factors will have to be considered.

Seed Production Experiment

Inadequate seed production is one possible cause of regeneration failure, so an experiment was set up to compare the amount of seed produced in a stand that lacked advance reproduction with the seed produced in a similar stand that had adequate oak advance reproduction.

Two study sites were selected in the Licking Creek Valley on the Tuscarora State Forest near Mifflintown, Pa. The two sites were 1.6 miles apart; both supported stands of mixed oaks, hickory, and red maple (table 1). Area A is an area of 10 to 20 acres that contained abundant oak reproduction (5,250 oak seedlings per acre). Area B is typical of many oak stands in the vicinity in that it contained very little oak advance reproduction (tallies showed only 96 oak seedlings per acre). Although overstory stocking was somewhat lower in the

Table 1.—Overstory and understory on study areas A and B

Area	White oak	Chestnut oak	Red oak	Scarlet oak	Black oak	Hickory	Red maple	Other	Total
				OVERSTORY BASAL AREA[1]					
				Square feet per acre					
Area A	21	2	10	31	8	2	9	3	86
Area B	10	12	10	2	13	31	14	4	96
				UNDERSTORY SEEDLINGS[2]					
				Thousands per acre					
Area A	1.1	0.6	3.3	0.0	0.3	0.2	14.7	2.7	22.7
Area B	(*)	0.0	(*)	0.0	(*)	0.4	6.2	3.9	10.5

[1] Includes all trees 0.5 inch dbh and larger. Tree of average basal area: Area A = 7.6 inches; Area B = 6.2 inches.
[2] Includes all stems less than 0.5 inch dbh.
* Less than 0.05 thousand per acre.

stand with abundant advance reproduction, this did not seem to be the primary reason for presence of advance seedlings; partial cuttings in adjacent stands had failed to stimulate formation of advance regeneration.

Within each of the two areas, six dominant northern red oak trees were selected for seed trapping. All selected trees seemed to have good acorn crops when examined during early August 1973, a year of heavy red oak seed crops in much of Pennsylvania. A large trap was erected beneath the crown of each selected tree. Each trap was 12 to 14 feet wide and 20 to 35 feet long, constructed of sheet plastic supported over galvanized wire supports and arranged with one end and both sides elevated so that acorns falling onto the plastic would roll to the lower end where they fell into a rodent-proof hardware-cloth basket. The total trap areas were equal in the two stands.

Collections of acorns were made weekly throughout the late summer and fall of 1973. Acorns were counted, and samples from each trap and each collection period were tested for soundness and germination. Acorns were removed from their seedcoats to judge soundness. They were considered sound if the embryo seemed intact, even though portions of the meat may have been destroyed by insects. The excised seeds were germinated on moist Kimpack at room temperature for 30 days for estimating viability.

Severe windstorms during the second week in October shattered many of the seed traps, and some of the total acorn crop was lost. The traps were repaired, and additional collections were made in November; but acorns that fell during the last half of October were lost and are not included in the data that follow. In spite of the fact that the data do not represent the entire 1973 crop, the relationships observed are revealing.

There were important differences in seed production between the two study areas. Area A, which had abundant oak advance reproduction, produced more seed than area B (2,815 versus 1,752), and a larger proportion of it was sound (54 percent versus 28 percent). Germination tests showed that germination rates were three times higher for acorns from area A than for those from area B. Thus the number of viable seed trapped on the area with good advance reproduction was about five times higher than that from the area with poor advance reproduction (table 2).

Table 2.—Summary of 1973 collections from seed-trap baskets

Item		Area A	Area B
Total seed collected	No.	2,815	1,752
Total sound[1]	No.	1,533	498
	Percent	54	28
Total germination	No.	1,027	206
	Percent	36	12

[1] Calculated from the samples on which percent soundness and percent germination were determined.

The damaged and unsound seed found in all acorn collections were the result of feeding by one of several insects *(Nichols 1975)*. The most important of these seemed to be an acorn weevil belonging to the genus *Curculio* and a moth, *Melissopus latiferreanus* (Wlsm.). The adults of both these insects deposit their eggs in the developing acorn, and the resulting larvae consume the nutmeat, usually before the acorn has fallen to the ground. Some of the nuts infested by *Curculio* are not completely eaten and may still be capable of germination. *Curculio* larvae usually emerge from the nut after it falls to the ground, leaving a circular hole in the shell. *Melissopus* larvae usually consume the nutmeat completely and may emerge while the acorn is still on the tree, then infest adjacent nuts before completing their growth. *Melissopus* pupates over winter in the leaves on the forest floor, while *Curculio* overwinters deeper in the soil *(Gibson 1969 and 1972)*.

There seems to be great variation from place to place, even within a relatively small area, in the prevalence of these insects. Additional acorns were collected from the ground in three stands on the Tuscarora State Forest and two stands on the Allegheny National Forest in Warren County, Pennsylvania. In some stands, virtually all acorns were destroyed; in others, very few were affected. Although the number of stands sampled is not adequate for drawing definite conclusions, it seems that insect damage to acorns may contribute significantly to the oak regeneration problem.

Seed Predation and Germination Experiment

The objective of this experiment was to compare the germination of acorns sown under a forest canopy in a stand containing oak advance reproduction with that in a stand lacking oak advance reproduction, and to determine what effect seed consumption by deer or rodents had on seedling establishment under these two stand conditions.

During the fall of 1973, six clusters of three plots each were laid out in each of the two areas previously described for the seed-trapping experiment. Each plot was 3 feet square. Twenty apparently sound undamaged red oak acorns from two seed sources (10 acorns from each source) were sown on each plot by pushing them into the humus until they were ½ to 1 inch below the surface. Laboratory germination tests indicated that viability of the seed sown averaged above 80 percent.

The three plots in each cluster were randomly assigned to one of the following treatments:

1. Protection from both deer and rodents by a ¼-inch-mesh hardware-cloth screen 3 x 3 x 1 foot surrounding the plot on all sides and the top, with the sides buried 4 to 6 inches into the soil.
2. Protected from deer only by a cattle-wire fence approximately 4 feet high and 4 feet in diameter around the plot.
3. Control, unprotected.

Counts of germination and survival were made at monthly intervals throughout the 1974 growing season. They showed that acorn pilferage by rodents was severe in area B, where advance oak reproduction was scarce, but was relatively unimportant in area A, where oak advance reproduction was abundant (table 3). We do not know why rodent pilferage was so much less in area A than in area B.

Table 3.—Total acorn germination in seed predation and germination experiment

[In percent of seed sown]

Area	Control	Protected from deer only	Protected from deer and rodents
Area A	33	28	32
Area B[1]	2	9	53

[1] Differences between treatments were statistically significant in area B, but not in area A.

Direct-Seeding Experiment

Anticipating the possibility that acorn supply may be limiting to oak reproduction, we began a direct-seeding experiment in the fall of 1973 to test the possibilities of sowing acorns in several types of plastic sleeves to protect the acorns from rodent pilferage.

The seeding experiment was laid out in area B (described previously—the stand lacking advance oak reproduction). Eight lines 100 feet long were laid out at random locations in area B, and 40 apparently sound red oak acorns were sown at uniform spacing along each line. Ten acorns at each line were randomly assigned to one of the following four treatments:

1. Plastic protector, ½-inch diameter, 6 inches long.
2. Plastic protector, 1-inch diameter, 6 inches long.
3. Plastic protector, 2-inch diameter, 6 inches long.
4. Control—no protection.

Sowing was accomplished during the first week of November by punching a hole an inch or so deep into the soil, using a soil-sampling tube of appropriate size. The protector was placed in the hole thus created, an acorn was dropped inside the protector, and the plug of soil from the sampling tube was then placed in the protector on top of the acorn so that the acorn was about 1 inch below the surface. A similar procedure was used on the control, except that the protector was omitted. Observations of seed germination and survival were made monthly throughout the 1974 growing season.

Rodent pilferage was extremely high in all four treatments during the late winter and spring months. The plastic tubes offered little or no protection from rodents. Many tubes were pulled out of the ground and the acorn was removed from them. In other cases, the rodents cut their way through the side of the tubes to get at the acorns. Overall germination averaged less than 10 percent, with no statistically significant differences among treatments.

Although the direct-seeding and the plastic protectors both failed, the experiment served to emphasize the extent and impact of rodent pilferage in the study area.

Planting Experiment

As a result of the failure to obtain established seedlings from direct-seeded acorns, it seemed apparent that planting of nursery-grown seedlings offered one way to circumvent acorn depredation. Previous attempts to plant oak seedlings in uncut stands and clearcut openings had not been very successful—presumably because of deer browsing and unfavorable environmental conditions. Therefore an experiment was set up to test planting under three levels of overstory density, using two sizes of nursery stock, both with and without protection from deer browsing.

Two new study areas were selected on the Tuscarora State Forest, one in the Licking Creek Valley and one in the Black Log Valley. Oak advance regeneration was scarce in both areas. Five blocks of three plots each were laid out in the two stands. Each plot was 3 x 3 chains (0.9 acres) and each plot was assigned to one of the following overstory density treatments:

1. Residual stocking 100 percent.
2. Residual stocking 60 percent.
3. Residual stocking 30 percent.

In all cases, stocking levels were based on basal area and average stand diameter, using the stocking charts developed by Roach and Gingrich *(1968)*.

Red oak seedlings were planted in the central 1/10 acre of each plot, in 4 rows of 12 seedlings each. The rows represented subplots and were assigned one of the following four treatments:

1. Large stock, protected against deer browsing by a 4-foot high, 1 foot-diameter chicken-wire fence.
2. Large stock, unprotected.
3. Small stock, protected as in 1 above.
4. Small stock, unprotected.

The small stock was the size normally supplied by the Pennsylvania state nurseries. The small red oak seedlings averaged 0.4 foot in height and 0.10 inch in diameter 2 inches above the root collar. The large stock was obtained from the same source by selection of the largest seedlings available. They averaged 1.3 feet in height and 0.22 inch diameter.

The plots were thinned during April 1975, and seedlings were planted and deer fences erected during the first 3 weeks of May 1975. Tallies of survival, height growth, and numbers of seedlings on which the terminal shoot had been browsed were made once a month during the 1975 growing season.

Several additional years will be required to evaluate the effect of the different residual stocking levels on growth and survival of the planted seedlings. But the impact of deer browsing was clearly apparent after just one season. Most of the unprotected seedlings have already been browsed several times (table 4).

Some of the smaller seedlings, and a few seedlings planted where logs or slash afford some protection, have escaped browsing so far; but it seems apparent that they too will be browsed as soon as they grow a little taller. To date, mortality has been low, but the browsing has been so severe and so frequent that we expect few of the unprotected seedlings to survive for more than a few years.

Growth of many seedlings has been negative: browsing has reduced their height below that at the time of planting. Even a few protected seedlings—whose terminals grew close enough to the chicken-wire mesh to be reached by deer—have been browsed.

Table 4.—Deer browsing on planted seedlings

[In percent browsed]

	Red oak
Fenced:	
Large seedlings	4
Small seedlings	(*)
Both sizes	2
Unfenced:	
Large seedlings	88
Small seedlings	49
Both sizes	69

* Less than 1 percent.

Discussion

The results suggest that the lack of oak advance regeneration in study area B may be due to destruction of seed by acorn insects, plus pilferage of the remaining acorns by rodents. There do not seem to be enough viable acorns surviving the winter to produce new seedlings. No new wild seedlings were observed anywhere in study area B, even though the 1973 acorn crop had been heavy. The seriousness of this situation may be illustrated by the fact that, of the 1,752 acorns trapped in area B, only about 10 could be expected to germinate in the field (498 of the 1,752 acorns trapped were sound, and only 2 percent of the sound unprotected acorns germinated in the field experiment).

The results also suggest that there may be large differences in the amount of insect and rodent depredation in stands located fairly near one another. In study area A, for example, 2,815 acorns were trapped, of which 506 could be expected to germinate in the field—almost 60 times as many as in area B. Of the 2,815 acorns trapped, 1,533 were sound, and 33 percent of the sound unprotected acorns germinated in the field experiment.

That such variations do occur consistently is evidenced by the large differences in the amounts of advance oak regeneration present under these two study stands. Although our studies have been limited to one geographic region in Pennsylvania, the findings of these studies, and observations made in other parts of the problem area, suggest that lack of viable acorns is probably the primary cause of oak advance regeneration failure in Pennsylvania. Because of this, shelterwood cuttings or other cutting methods intended to stimulate natural regeneration are not likely to produce satisfactory results unless some practical methods can be found to control rodent and insect damage to acorns.

Direct-seeding does not seem particularly promising in oak problem areas because of the severe rodent depredations. Unless effective repellents or practical controls are found, planting seems to be the most promising method of regenerating oaks for the immediate future. But even planting does not eliminate all problems. Planted seedlings are severely browsed by deer, and success will be unlikely unless deer populations are reduced or the seedlings are protected from browsing with wire fences, plastic sleeves, or other similar devices.

Thus, oak regeneration problems throughout much of Pennsylvania may be due to the combined action of acorn insects, rodents, and deer, all of which must be taken into account before successful regeneration can be obtained. Much additional research is needed to find practical methods of circumventing these problems.

Literature Cited

Gibson, Lester P.
1972. INSECTS THAT DAMAGE WHITE OAK ACORNS. USDA For. Serv. Res. Pap. NE-220. 7 p.

Gibson, Lester P.
1969. MONOGRAPH OF THE GENUS *Curculio* IN THE NEW WORLD (COLEOPTERA : CURCULIONIDAE). PART I. UNITED STATES AND CANADA. Entomol. Soc. Am. Misc. Publ. : 6(5) : 241-285.

Nichols, James O.
1975. QUARTERLY REPORT, PENNSYLVANIA DIVISION OF FOREST PEST MANAGEMENT. Pa. Dep. Environ. Resour. Bur. For. Harrisburg. 4 p.

Nichols, James O.
1973. ANNUAL REPORT OF OPERATIONS AND FOREST PEST CONDITIONS. Pa. Dep. Environ. Resour., Bur. For., Div. Pest Manage. Harrisburg. 21 p.

Sander, Ivan L., and Clark, F. Bryan.
1971. REPRODUCTION OF UPLAND CENTRAL HARDWOOD FORESTS IN THE CENTRAL STATES. U. S. Dep. Agric. Handb. 405. 25 p.

Roach, Benjamin A., and Gingrich, Samuel F.
1968. EVEN-AGED SILVICULTURE FOR UPLAND CENTRAL HARDWOODS. U. S. Dep. Agric. Handb. 355. 39 p.