EVALUATION OF AN APPROACH TO IMPROVE ACORN PRODUCTION DURING THINNING

William E. Drake[1]

Abstract: Large poletimber size, mixed oak (*Quercus* spp.) stands in Centre County, Pennsylvania were thinned to determine whether acorn production could be improved by retaining the best acorn producing oaks as compared with conventional thinning practices. Sound acorn production averaged 291 and 339 kg/ha in the acorn production and conventionally thinned stands, respectively, prior to thinning. Average yields declined by 79 and 129 kg/ha in the acorn production and conventionally thinned stands, respectively, following thinning. Although declines were less in stands thinned for acorn production, they were not significantly different ($P>0.25$) from those in conventionally thinned stands. Crown dominance was an important factor affecting acorn production in this study. Ninety-six and 76 percent of the dominant and co-dominant oaks produced acorns. Conversely, only 40 and 8 percent of the intermediate and suppressed oaks were productive. Results of this study indicate that improvements in acorn yields were not sufficient to justify the additional effort and cost of identifying and retaining to best acorn producing oaks prior to thinning.

INTRODUCTION

Factors affecting the acorn production of oaks have been intensively studied over the years because of the importance of acorns in regenerating oak stands and as a food source for many wildlife species. Vigorously growing oaks with well developed crowns are regarded as generally superior acorn producers (Downs and McQuilken 1944, Cypert 1951, and Sharp 1958). Numerous studies also indicate that some individual oaks are consistently good or poor acorn producers and suggest that this may be due to their inherent genetic potential for producing acorns (Downs and McQuilken 1944, Harlow and Eikum 1963, Sharp and Sprague 1967, Goodrum et al. 1971, and Christisen and Kearby 1984).

Harlow and Eikum (1963), Sharp and Sprague (1967), Shaw (1971) and Goodrum et al. (1971) recommended that good acorn producing oaks be retained during thinning to improve acorn yields relative to conventionally thinned stands. This study was undertaken to evaluate the effectiveness of such a recommendation.

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[1]Wildlife Biologist, Pennsylvania Game Commission, 2001 Elmerton Ave., Harrisburg, PA 17110-9797.

I would especially like to thank S. A. Liscinsky for initiation of this study as well as his guidance and support until its completion. Pennsylvania Game Commission wildlife technicians, biologists and foresters assisted with field work and data collections. R. C. Boyd, W. L. Palmer, W. K. Shope and W. M. Tzilkowski provided statistical assistance. The study was funded by the Pennsylvania Game Commission.

METHODS

Study Sites

Three mixed oak stands were selected as study sites (replications). Two of the stands were on State Game Lands No. 33 and the third one was on State Game Lands No. 60 near Philipsburg in Centre County, Pennsylvania. All 3 stands were within 3.2 km of each other. Three replications were in fully stocked large poletimber size, mixed oak stands ranging from 42 to 58 years of age. The basal area, mean d.b.h. and percentage of oak in the 3 replications are given in Table 1. Measurements of site index within and between replications were not taken.

Table 1.--Basal area, mean d.b.h. and percentage of oak in 3 replications.

Replication	Basal Area (m^2/ha)	Mean d.b.h. (cm)	% Oak[a]
1	24.2	19.6	69
2	19.9	23.9	66
3	21.7	20.1	75

[a]Includes red oak (*Quercus rubra*), black oak (*Q. velutina*), scarlet oak (*Q. coccinea*), white oak (*Q. alba*) and chestnut oak (*Q. prinus*).

Study Design

A 3 x 3 randomized block design was used with 3 treatments within each replication:

1. Acorn production thinning (APT) - trees were selected for retention during thinning according to their acorn production.
2. Conventional thinning (CT) - trees were selected for retention during thinning according to conventional thinning criteria.
3. Control (C) - unthinned.

Treatments were applied on adjacent 0.8 ha square blocks in each replication. Assignment of treatment to blocks within replications was random.

Treatments

All oaks in the 3-0.8 ha APT treatment blocks were tagged with aluminum labels. Their potential for acorn production was evaluated by inspection of branches in the crown with binoculars (Sharp 1958). Numbers of acorns on the 6 most heavily bearing branches were counted for each oak (1,318 trees) for 3 years prior to thinning (1974 thru 1976). Those oaks with the best acorn production for 3 years prior to thinning were retained in APT treatment blocks. All non-oaks were removed first during thinning to maximize acorn yields. Then all non-producing and a few of the poorest producing oaks were removed until residual basal area in the APT blocks was the same as that in the CT blocks. Also, each of the oaks in the APT blocks were visually inspected prior to thinning and placed in a dominant, co-dominant, intermediate or suppressed crown dominance category.

CT treatment blocks were thinned by Pennsylvania Game Commission foresters. In addition to conventional silvicultural considerations such as commercial value, spacing and crown dominance, den trees, snags and less common tree species and shrubs were retained for their value to wildlife. C treatment blocks were left untreated to compare their acorn yields with those in both thinning treatments.

Table 2.--Pre-thinning species composition (% of basel area) in APT and CT treatments for 3 replications - January, 1977.

Species	Replication #1		Replication #2		Replication #3	
	APT	CT	APT	CT	APT	CT
red oak	32	30	25	26	59	49
black oak	23	20	8	18	5	8
scarlet oak	10	6	10	11	3	3
white oak	4	2	16	9	3	1
chestnut oak	5	6	6	8	4	15
red maple	25	35	35	28	20	18
sassafras	1	trace	0	0	5	4
hickory spp.	trace	1	0	trace	1	2
black gum	0	0	0	0	trace	trace
aspen spp.	0	0	0	0	0	trace
Totals	100	100	100	100	100	100

In January, 1977, diameter measurements of all trees in all 3 replications of the APT and CT treatment blocks were conducted to determine pre-thinning species composition (Table 2), size class composition and basal area (Table 3). Prism plot cruises were used to determine basal area in the C blocks. Pre-treatment basal area means were 22.9, 23.9 and 20.7 m^2/ha in the APT, CT, and C treatment blocks, respectively .

Table 3.--Pre-thinning size class composition (% of basal area) in APT and CT treatments for 3 replications - January, 1977.

Size class (dbh-inches)	Replication #1 APT	Replication #1 CT	Replication #2 APT	Replication #2 CT	Replication #3 APT	Replication #3 CT
2	39	42	49	55	37	32
4	22	20	13	9	23	26
6	15	15	12	11	15	18
8	13	14	15	12	17	15
10	8	6	5	7	6	7
12	1	2	3	4	2	2
14	1	1	2	2	trace	trace
16	1	trace	1	trace	0	trace
18	trace	trace	trace	trace	trace	trace
20	trace	trace	trace	0	0	trace
22	0	0	0	0	0	0
24	0	0	0	trace	0	trace
BA(ft^2/acre)	99.0	103.0	94.3	104.6	105.7	105.3
BA(m^2/ha)	22.7	23.6	21.7	24.0	24.3	24.2

In March, 1977, the CT blocks were reduced by about 30 percent to 16.3 m^2/ha of basal area using established forestry and wildlife practices. The APT blocks were thinned to the same basal area by removal of all non-oaks as well as the non-producing and poorest acorn producing oaks. Post-thinning APT treatment species and size class composition for Replications #1, #2 and #3 are in Tables 4, 5 and 6, respectively. Post-thinning CT treatment species and size class composition for Replications #1, #2 and #3 are in Tables 7, 8 and 9, respectively.

Beginning in the 1980 growing season, the study area experienced 5 years of gypsy moth (*Lymantria dispar*) defoliation. Defoliation was moderate in 1980, nearly complete in 1981 and 1982, light in 1983 and very light in 1984. By 1984, there was significant oak mortality throughout all 3 replications. To insure equal stocking levels following mortality, the basal area of all live trees in the APT and CT blocks was measured in May of 1984 and June of 1985 and 1986. By 1984, basal area in the APT blocks had had declined by an average of 34 percent from the original thinning in 1977. CT blocks had consistently less mortality. Basal area in the CT blocks was the same in May, 1984 (16.1 m^2/ha) as that remaining following

Table 4.--Post-thinning species and size class composition (ft²acre) in Replication #1 - APT treatment - March, 1977.

Size Class (dbh - inches)	Species: Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	TOTALS	%
2							0
4					0.2	0.2	trace
6	1.0	0.2	1.4		1.6	4.2	6
8	9.1	2.4	4.5	0.7	1.8	18.5	26
10	12.1	2.8	3.3	0.5		18.7	26
12	3.1	3.2	1.6			7.9	11
14	1.1	7.5		1.0		9.6	14
16	1.4	2.8				4.2	6
18		5.3				5.3	8
20		2.2				2.2	3
TOTALS	27.8	26.4	10.8	2.2	3.6	70.8*	
%	39	38	15	3	5		100

*BA = 16.3 m^2/ha

the initial thinning in 1977 - a result of compensating growth and mortality. Sufficient trees were removed in the CT blocks in June of 1984, 1985 and 1986 to equalize basal area between APT and CT treatments throughout the study. Residual basal area in the APT and CT treatments during the 1984, 1985 and 1986 growing seasons were less than one-half their pre-thinning levels (Table 10).

Prism cruise basal area measurements in the C blocks were only taken at the beginning and upon completion of the study. Mean basal area in the 3 C blocks had declined by 24 percent by June of 1986 from pre-thinning levels (Table 10).

Acorn Production Measurement

Pre- and post-thinning acorn production was sampled in 9-0.8 ha treatment blocks (3 replications of 3 treatment blocks each). Sampling was done on a 0.4 ha sampling area in each block surrounded by 12.2 m buffer strip to avoid an edge effect from adjacent treatments.

Sixty acorn traps were systematically located in each sampling area. Acorn traps were constructed with plastic bags with bottoms removed and tied and supported by wire hoops on posts (Liscinsky 1971). Each trap was 48.3 cm in diameter (0.13 m^2 sample area) resulting in

Table 5.--Post-thinning species and size class composition (ft^2/acre) in Replication #2 - APT treatment - March, 1977.

Size Class (dbh - inches)	Species Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	TOTALS	%
2						0.0	0
4						0.0	0
6				0.6	0.8	1.4	2
8	1.8		2.1	5.2	3.1	12.2	17
10	8.8	2.2	3.3	7.2	1.6	23.1	33
12	8.7	0.8	3.1	2.4	0.8	15.8	23
14	5.4	1.1		2.1		8.6	12
16	5.6	1.4				7.0	10
18						0.0	0
20	2.2					2.2	3
TOTALS	32.5	5.5	8.5	17.5	6.3	70.3*	
%	46	8	12	25	9		100

*BA = 16.1 m^2/ha

7.8 m^2 being sampled in each sampling area. Four collections were made each fall. Sound acorns captured were weighed within 24 hours of collection. Weights were converted to estimates of sound acorn production in kg (fresh weight) per ha.

All 9 treatment blocks were sampled for 3 years (1974 thru 1976) to obtain estimates of mean pre-thinning acorn production. Each treatment block was then sampled for 10 years (1977 thru 1986) to determine post-thinning means.

Data Analysis

Friedman's randomized block analysis of variance test was used to test the H_o that changes in acorn yields following thinning were the same for all 3 treatments. Since mean pre-thinning acorn yields were not equal in all 3 treatments, comparisons of response to the 2 types of thinning were based on percentage changes in mean acorn yields following these thinnings. X^2 tables were used to determine the significance of Friedman's critical value (X^2r, P=0.05, 2 df, Zar 1974).

The Kruskal-Wallis single factor analysis of variance by ranks test was used to test the H_o that the percentage of oaks in the APT treatment blocks producing acorns was the same regardless of crown dominance ($H_{0.05,3,3,3,3}$, Zar 1974).

Table 6.--Post-thinning species and size class composition (ft^2/acre) in Replication #3 - APT treatment - March, 1977.

Size Class (dbh - inches)	Species: Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	TOTALS	%
2						0.0	0
4						0.0	0
6	3.2	0.4		0.2	0.8	4.6	6
8	21.0	1.4	1.7		2.1	26.2	36
10	23.7	2.2	1.1		0.5	27.5	38
12	8.7	1.6				10.3	14
14	1.0	1.1				2.1	3
16						0.0	0
18				1.8		1.8	3
TOTAL	57.6	6.7	2.8	2.0	3.4	72.5*	
%	79	9	4	3	5		100

*BA = 16.6 m^2/ha

RESULTS AND DISCUSSION

Annual Acorn Production Trends

Trends in mean acorn production in 3 treatments over 13 years are presented in Table 11. As in other studies (Downs and McQuilken 1944, Goodrum et al. 1971, and Christisen and Kearby 1984), acorn yields varied considerably between years. There were bumper crops (>700 kg/ha or > 600 pounds/acre) of acorns in 3 of 13 years. One (1976) was before and 2 (1979 and 1985) were after thinning (Figure 1). Only 1 other year (1984) had mean acorn yields in excess of 150 kg/ha. The acorn crops of 1980 thru 1984 were heavily affected by gypsy moth defoliation. Trends in annual acorn yields between treatments were fairly consistent throughout the study. All treatments had excellent yields in bumper years and vice versa in years of poor acorn production.

Acorn Production Thinning Versus Conventional Thinning

Mean pre-thinning acorn yields for APT and CT treatment blocks were 291 and 339 kg/ha, respectively. Mean acorn yield declined during the 10 years following thinning in both APT

Table 7.--Post-thinning species and size class composition (ft^2/acre) in Replication #1 - CT treatment - March, 1977.

Size Class (dbh - inches)	Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	Others**	TOTALS	%
	Species							
2		trace				trace	trace	trace
4					0.1	0.2	0.3	1
6	0.6	0.4	0.4	0.2	0.4		2.0	3
8	12.6	3.9	1.7		1.4		19.6	28
10	18.1	5.5	2.8	0.5		0.6	27.5	39
12	4.7	3.2					7.9	11
14		2.1	1.1		1.1		4.3	6
16		1.4	1.4				2.8	4
18		3.5					3.5	5
20		2.2					2.2	3
TOTALS	36.0	22.2	7.4	0.7	3.0	0.8	70.1*	
%	51	32	11	1	4	1		100

*BA = 16.1 m^2/ha

**Includes red maple, hickory spp. and sassafras.

and CT blocks to 217 and 210 kg/ha, respectively (Table 11). Post-thinning declines may have been partially due to gypsy moth defoliation. Acorn yields declined less following thinning in the APT blocks (-74 kg/ha) than in the CT blocks (-129 kg/ha). Friedman's test indicated that changes in acorn yields were not different (X^2r=1.962, P>0.25, 2 df) regardless of the thinning techniques used.

There could be several reasons why acorn yields were not improved significantly by retaining the best acorn producing oaks during thinning. Perhaps oaks with the best genetic potential for consistantly good acorn production were not well identified by counting acorns on the 6 best producing branches. However, this should be a practical phenotypic criteria for selecting oaks with the best genetic potential for acorn production (Sharp 1958). In addition, all 5 oak species (red, black, scarlet, white and chestnut) had at least 1 year of good acorn production during the 3 years when branches were inspected prior to thinning. All 5 oak species had at least fair acorn production during the bumper 1976 crop. If poor or superior acorn producing oaks are relatively consistant in this respect, they should have been easily identified.

Results of this study were heavily influenced by bumper acorn yields in 1979 and 1985. Perhaps continuation of the study would have given different results. However, if the acorn production potential of the oaks retained during thinning was a relatively consistant factor affecting acorn yields, it should have been demonstrated in these bumper years.

Table 8.--Post-thinning species and size class composition (ft²/acre) in Replication #2 - CT treatment - March, 1977.

Size Class (dbh - inches)	Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	Others**	TOTALS	%
	Species							
2	0.2	trace		trace		0.2	0.4	1
4			0.1			0.3	0.4	1
6				0.2	0.2	0.2	0.6	1
8	1.7	2.5	0.7	1.1	0.7		6.7	9
10	4.9	6.6	2.7	1.7	2.7	0.6	19.2	26
12	8.7	4.7	2.4	0.8	0.8		17.4	24
14	11.8	2.1	3.2				17.1	24
16	2.8	1.4	1.4				5.6	8
18				1.8			1.8	2
20							0.0	0
22							0.0	0
24	3.1						3.1	4
TOTALS	33.2	17.3	10.5	5.6	4.4	1.3	72.3*	
%	46	24	14	8	6	6	2	100

*BA = 16.6 m²/ha

**Includes red maple and hickory spp.

Crown Dominance Versus Acorn Production

Studies by Downs and McQuilken (1944), Cypert (1951), Burns et al. (1954), Sharp and Sprague (1967) and Goodrum et al. (1971) have indicated the importance of crown dominance on acorn yields. The importance of crown dominance was also apparent in the study. Ninety-six and 76 percent of the dominant and co-dominant oaks produced acorns, respectively. Conversely, only 40 and 8 percent of the intermediate and suppressed oaks, respectively, were productive (Table 12). Crown dominance was an extremely important factor ($H=10.37$, $P<0.001$) influencing whether or not oaks in the APT treatment blocks produced acorns.

All the non-producing oaks as well as some of the poorest producers, were removed during thinning. Poorest producing oaks also tended to be suppressed and intermediates. Since many of the suppressed and intermediates were removed in the CT blocks, size class distributions of trees retained in the APT blocks were similar to those in the CT blocks (see Tables 4 through 9). Even the spacing of residual trees was observed to be similar in the

Table 9.--Post-thinning species and size class composition (ft²/acre) in Replication #3 - CT treatment - March, 1977.

Size Class	Species							
(dbh - inches)	Red Oak	Black Oak	Scarlet Oak	White Oak	Chestnut Oak	Others**	TOTALS	%
2						0.1	0.1	trace
4						0.3	0.3	1
6	2.4	0.4	0.2	0.2	0.4	1.0	4.6	6
8	14.0	1.8	0.3	0.4	4.5	1.1	22.1	31
10	19.8	2.7	1.7		2.2	0.5	26.9	38
12	8.7				0.8		9.5	14
14	1.0	1.1					2.1	3
16		1.4	1.4				2.8	4
18							0.0	0
20		2.2					2.2	3
TOTALS	45.9	9.6	3.6	0.6	7.9	3.0	70.6*	
%	65	14	5	1	11	4		100

*BA = 16.2 m²/ha
**Includes red maple, hickory spp., sassafras, aspen spp., and blackgum.

Table 10.--Mean basal area (m²/ha) in 3 treatments.

Date	Treatment		
	APT*	CT*	C**
		Prior to thinning	
January, 1977	22.9	23.9	20.7
		Following thinning	
March, 1977	16.3	16.3	?
		Following gypsy moth mortality	
May, 1984	10.6	16.1	?
June, 1984	10.6	10.6	?
June, 1985	10.3	10.3	?
June, 1986	11.3	11.3	15.6

* Based on diameter measurement of all trees in 3 replications.
**Based on 10 BAF-10 prism plots in all 3 replications.

Table 11.--Mean pre- and post-thinning acorn production for 3 treatments*.

Year	Treatment APT	CT	C
	Pre-thinning		
1974	44	39	44
1975	46	35	79
1976	783	944	658
Mean (3 yrs.)	291	339	260
	Post thinning		
1977	22	33	33
1978	5	2	7
1979	771	952	618
1980	93	62	68
1981	0	5	11
1982	0	1	0
1983	0	8	2
1984	63	293	122
1985	1081	680	734
1986	135	59	30
Mean (10 yrs.)	217	210	163
Change	-74	-129	-97
% change	-25.4	-38.1	-37.5

*Figures represent mean (for 3 replications) estimated sound acorn production in kg (fresh weight)/ha.

Table 12.--Percentage of producing oaks, by crown dominance category in 3 APT replications- 1974 thru 1976.

Replication	Crown Dominance Category Dominant	Co-Dominant	Intermediate	Suppressed
1	90.7	71.3	30.0	0.0
2	97.8	80.9	53.5	9.7
3	100.0	75.3	37.2	13.9
Mean	96.2	75.8	40.2	7.9

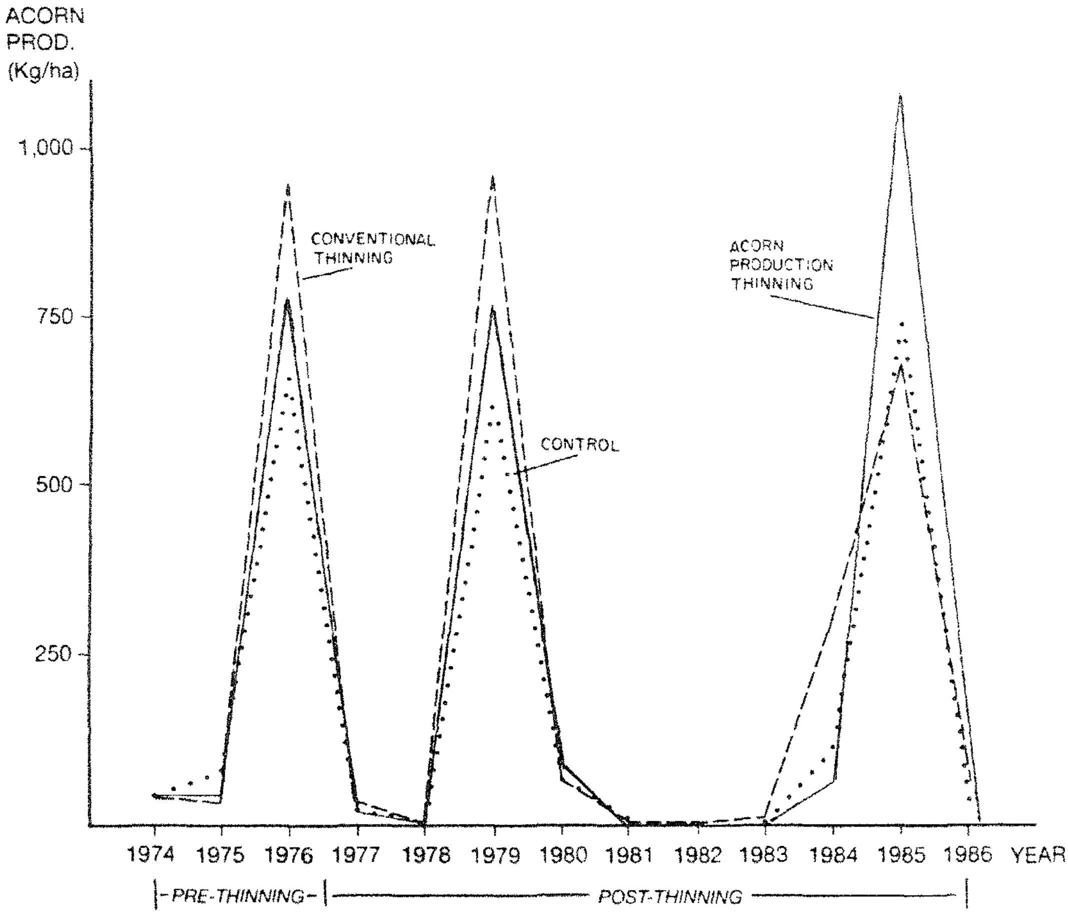

Figure 1. Mean pre- and post-thinning acorn production for three treatments.

APT and CT blocks. This may have been due to the majority of dominants and co-dominants being retained and the similarity of their spacing in both treatment blocks.

The importance of crown dominance may partially explain why acorn yields were not improved by retaining the best producers. Perhaps the suppressed and intermediate oaks with good genetic potential for acorn production did not display a phenotype expression of their potential (i.e. good acorn production) because of shading and were outproduced by dominants and co-dominants with moderate or even poor genetic potential whose crowns were exposed to higher intensities of sunlight. If so, it again reflects the importance of crown dominance relative to the selection of phenotypically superior acorn producers and points out the practical difficulty of improving acorn yields by retaining the best producers.

SUMMARY

Crown dominance was an important factor affecting the acorn production of individual oaks in this study. Conversely, acorn yields were not appreciably improved by retaining good acorn producing oaks during thinning relative to conventionally thinned stands. Results of this study indicate that improvements in acorn yields were not sufficient to justify the additional effort and cost of identifying and retaining the best acorn producing oaks prior to the thinning.

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