THE RELATIONSHIP BETWEEN BASAL AREA AND HARD MAST PRODUCTION IN THE OUACHITA MOUNTAINS

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Abstract—Because the relationship between stand density and hard mast production is not clear, we investigated the effects of varying total overstory basal area (BA) on acorn and hickory nut production in the Ouachita Mountains. We used Whitehead visual surveys to estimate mast production in oaks (*Quercus* spp.) and hickories (*Carya* spp.) located in 20 stands under five silvicultural treatments, each varying in residual BA. In 5 years of data (1994-1998), we found no linear relationship between BA and mast production for the red oak subgenus. A significant linear relationship existed between BA and hickory nut production two of the 5 years. A significant linear relationship existed between acorn production and BA for white (*Q. alba*) and post (*Q. stellata*) oaks all 5 years; trees in stands with lower BA had higher production indices. Because white and post oaks tend to be the dominant mast producers in pine-hardwood stands on south-facing slopes in the Ouachita Mountains, thinning these areas should generally increase mast production by residual trees. However, we did not measure the effects of thinning on stand-wide mast production.

INTRODUCTION

Hard mast production is an important element of forest ecology. Mast abundance affects both forest regeneration and wildlife that rely on mast as a food source. Many wildlife species are so dependent on hard mast that its supply may influence their condition, reproduction, movements, survival, and population parameters (McShea and Schwede 1993, Nixon and others 1975, Wentworth and others 1990).

For decades, researchers have investigated the factors influencing hard-mast (primarily acorns) production. Their efforts have provided considerable, and frequently conflicting, information on the variation in production among years, species, and individual trees. Moreover, these studies have provided many theories, from genetics to weather, to account for this variation (e.g., Christisen 1955, Christisen and Korschgen 1955, Downs and McQuilken 1944, Farmer 1981, Koenig and others 1996, Sork and others 1993). However, little is known on how forest management practices affect mast production.

Land managers who thin forest stands cite increased mast production as one of the benefits of thinning. Although the relationship between stand density and seed production has been thoroughly investigated in pines (*Pinus* spp.; e.g., Bilan 1960, Croker 1952, Godman 1962, Wenger 1954), information on oaks (*Quercus* spp.) and hickories (*Carya* spp.) is limited mostly to anecdotal and observational references (e.g., Gysel 1956, Minckler and McDermott 1960, Reid and Goodrum 1957, Sharp and Sprague 1967). Studies suggest a relationship may exist in oaks, but this relationship is poorly understood. For this study, we investigated the relationship between total (pine and hardwood) basal area (BA) and mast production by oaks and hickories to determine if reducing stand density increases the mast production of residual trees.

METHODS

Study Areas

Research was conducted in the 20 phase II wildlife stands of the USDA Forest Service Ouachita Mountain Ecosystem Management Research Project located in the Ouachita and Ozark National Forests of Arkansas and Oklahoma (Baker 1994). Sampling began the first year after four different silvicultural systems were applied to initially even-aged, pine-hardwood stands (approximately 40 acres each). Trees were surveyed in four replications of clearcut (with scattered overstory hardwoods retained for wildlife), single-tree selection, group selection, and shelterwood. Harvesting occurred in 1993. In addition, trees were surveyed in four closed-canopy, late-rotation unharvested stands (60-80 years old). For a complete description of stand treatments, see Baker (1994). Basal area estimates for trees ≥3.6 inches d.b.h. were derived using the method of Guldin and others (1994). Immediately after harvest, average total overstory BA within harvested portions of stands, excluding greenbelts, was 6.5 (1.3 pine and 5.2 hardwood) square feet per acre in clearcuts, 49.6 (36.1 pine and 13.5 hardwood) square feet per acre in shelterwoods, 67.5 (54.0 pine and 13.5 hardwood) square feet per acre in single-tree selection stands, 18.3 (1.3 pine and 17.0 hardwood) square feet per acre in group openings, and 88.8 (61.8 pine and 27.0 hardwood) square feet per acre in group selection matrixes. Average basal area among unharvested stands was 127.5 (98.8 pine and 28.7 hardwood) square feet per acre (Unpublished data. James M. Guldin, Forest Ecologist, USDA Forest Service, Southern Research Station, P.O. Box 1270, Hot Springs, AR 71902).

Production Estimates

In each stand, we sampled all oaks ≥7.9 in. d.b.h. and all hickories ≥5.9 in. d.b.h. (regardless of crown placement) located within 4 to 9 belt transects (depending on stand size and shape) that were parallel and 49.2-feet wide (Thill and

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Table 1—Mean (± SE) number of trees sampled in each stand or stand subtreatment, by species (or species group) and year, and the number of sample areas (N) included in the regression analysis between Whitehead mast indices and BA in the Ouachita Mountains, 1994–1998

	White oak		Post oak		Hickories		Red oak subgenus	
Year	Mean	N	Mean	N	Mean	N	Mean	N
1994	16.5 ± 1.86	13	17.4 ± 3.54	7	13.3 ± 1.37	8	20.5 ± 6.03	4
1995	18.8 ± 1.89	14	16.0 ± 3.26	10	15.5 ± 2.02	10	25.4 ± 8.73	5
1996	19.2 ± 2.32	14	17.4 ± 3.26	8	14.2 ± 1.42	10	20.0 ± 6.27	7
1997	22.1 ± 2.31	14	16.5 ± 3.08	10	17.8 ± 2.23	11	21.7 ± 7.98	6
1998	22.8 ± 2.40	14	16.8 ± 3.21	10	17.9 ± 2.26	11	19.9 ± 6.87	7

BA = basal area.

others 1994). Transects were 98 to 312 feet apart, perpendicular to slope contours, and >164 feet from the stand edge. Because residual mast-producing tree densities differed among treatment types, we sampled less area in stands with higher tree densities (unharvested, group selection matrix areas, and single-tree selection stands). Thus, total area sampled in each stand was 2.5-3.2 acres in unharvested stands, 2.3-3.5 acres in single-tree selection stands, 2.8-2.9 acres in group selection stands, 4.5-5.3 acres in shelterwood stands, and 5.1-5.3 acres in clearcut stands.

We sampled each stand in mid- to late-August of 1994-1998. Because of costs and biases associated with seed traps (Perry and Thill 1999), we derived indices of oak and hickory production using the Whitehead visual survey method (Whitehead 1969). These indices were derived by visually estimating percent of a tree's crown producing nuts, percent of twigs with nuts, and the average number of nuts per twig using binoculars. This method results in an index ranging from 0 (no production) to 10 (bumper crop) and can be useful for distinguishing differences in mast production among areas (Perry and Thill 1999).

Data Analysis

Within group selection stands, we considered group openings and the thinned matrix surrounding openings as separate treatments because of substantial differences in residual BA. Therefore, total number of stands and subtreatments was 24. We did not include trees located in greenbelts (unharvested buffers surrounding streams and drains) in the analysis; likewise, we excluded greenbelt BA from total stand BA calculations. We calculated a mean production index for each stand or subtreatment where at least eight trees of a species or species group existed within the sample area. We regressed each mean production index with the mean BA for that stand or subtreatment using linear regression (SAS Institute Inc. 1988) at the ≤0.10 level of probability. We regressed each year separately.

Oak and hickory species composition differed among stands because of site and/or geographic locality differences. Thus, post oaks (*Q. stellata* Wang.) were the dominant oak species in some stands but were absent in others, whereas white oaks (*Q. alba* L.) were the dominant oak in most stands. Furthermore, the densities of some mast species were too low to collect adequate sample sizes (≥8 trees per stand or subtreatment). Therefore, total number of areas used in regression equations did not reflect the total number of stands and subtreatments. Oaks of the red oak group (subgenus *Erythrobalanus*) were rare in most stands; therefore, we combined black (*Q. velutina* Lam.), northern red (*Q. rubra* L.), southern red (*Q. falcata* Michx.), and blackjack (*Q. marilandica* Muenchh.) into a single red oak group. We also combined mockernut hickory (*C. tomentosa* Nutt.) and black hickory (*C. texana* Buckl.) into a single hickory group. For each species or species group, the mean number of trees sampled ranged from 13.3-25.4 per stand or subtreatment and total number of stands or subtreatments in the analysis was 4-14 (table 1).

RESULTS AND DISCUSSION

Red Oak Subgenus

Among the combined species of the red-oak subgenus, we found no relationship between BA and production indices all 5 years (table 2). Healy (1997) found individual northern red oaks in New England stands thinned to 50 percent stocking produced more acorns than trees in unthinned stands. Paugh (1970) found individual red oaks in heavily thinned stands produced more mast than trees in unthinned stands, but trees in lightly thinned stands produced less mast than trees in unthinned areas. Harlow and Eikum (1963) found turkey oaks (*Q. laevis* Walt.) in stands thinned to 50 or 90 percent of their original BA produced more mast than trees in unthinned or 75 percent thinned stands. Although these studies suggest that heavy thinning promotes increased

Table 2—Statistics for the yearly relationship between BA and production indices for red oak species sampled in the Ouachita Mountains, 1994–1998

Year	*F*	*P*	df
1994	0.01	0.93	1,2
1995	0.02	0.89	1,3
1996	1.01	0.36	1,5
1997	0.00	0.99	1,4
1998	0.94	0.38	1,5

BA = basal area.

mast production, they also suggest a linear relationship between density and mast production may not exist for red oaks. However, grouping data from four species and small sample sizes may have adversely affected our analysis. Furthermore, much larger sample sizes are probably required to detect a relationship given the highly variable nature of mast production among individual trees, years, and areas.

White and Post Oaks

A significant relationship existed between BA and production indices in white oaks all 5 years of the study (fig. 1). Production indices decreased with increases in total overstory BA. This relationship was relatively weak ($r^2 = 0.31$) in 1994 and relatively strong ($r^2 = 0.71$) in 1995. A similar significant relationship existed between BA and production indices in post oaks all 5 years of the study (fig. 2), with the weakest relationship ($r^2 = 0.29$) occurring in 1997 and the strongest relationship ($r^2 = 0.63$) in 1996.

Yearly variations in acorn production did not appear to affect the strength of the relationship between production and BA. Among white oaks, the strongest relationship ($r^2 = 0.71$) was during a bumper-crop year (1995), whereas the weakest relationship was during an average production year (1994). The r^2 values in 1998 (a near mast-failure year), 1996 (an average year), and 1997 (an above average year) were similar. Yearly variation in production did not appear to affect the strength of the relationship in post oaks.

Equations describing the relationship between stand BA and mast production indices in white and post oaks differed each year, depending on the yearly level of production. Because of these yearly differences, we can only roughly calculate a predictive equation for the effect of BA on Whitehead index. An averaged equation for white oaks (all 5 years of data pooled) was: $y = 3.5\text{-}0.022x$, where y = the predicted mast index and x = BA (square feet per acre). For post oaks, the averaged equation was: $y = 4.3\text{-}0.030x$. For example, a total overstory BA of 25 square feet per acre will, on average, result in a white-oak index of 2.95, whereas a BA of 120 will average 0.86.

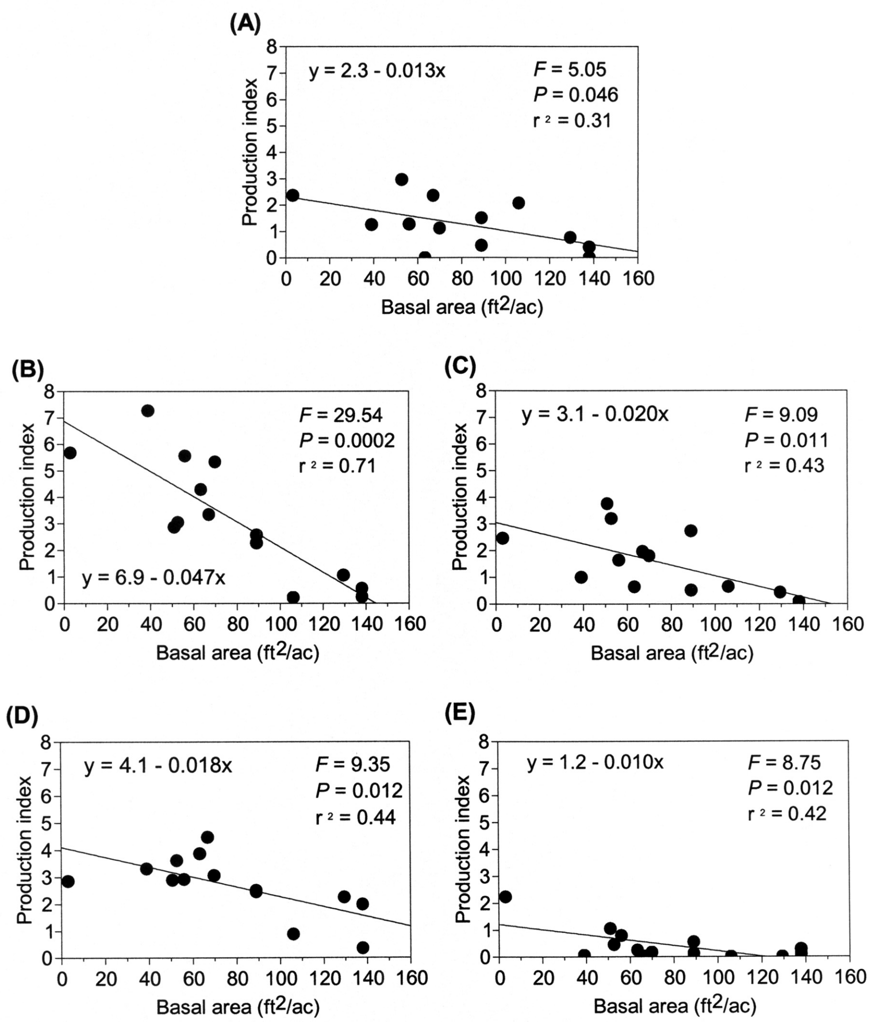

Figure 1—Yearly relationship (A = 1994, B = 1995, C = 1996, D = 1997 and E = 1998) between basal area and mean Whitehead mast production indices for white oaks (*Quercus alba*) in the Ouachita Mountains, 1994-1998.

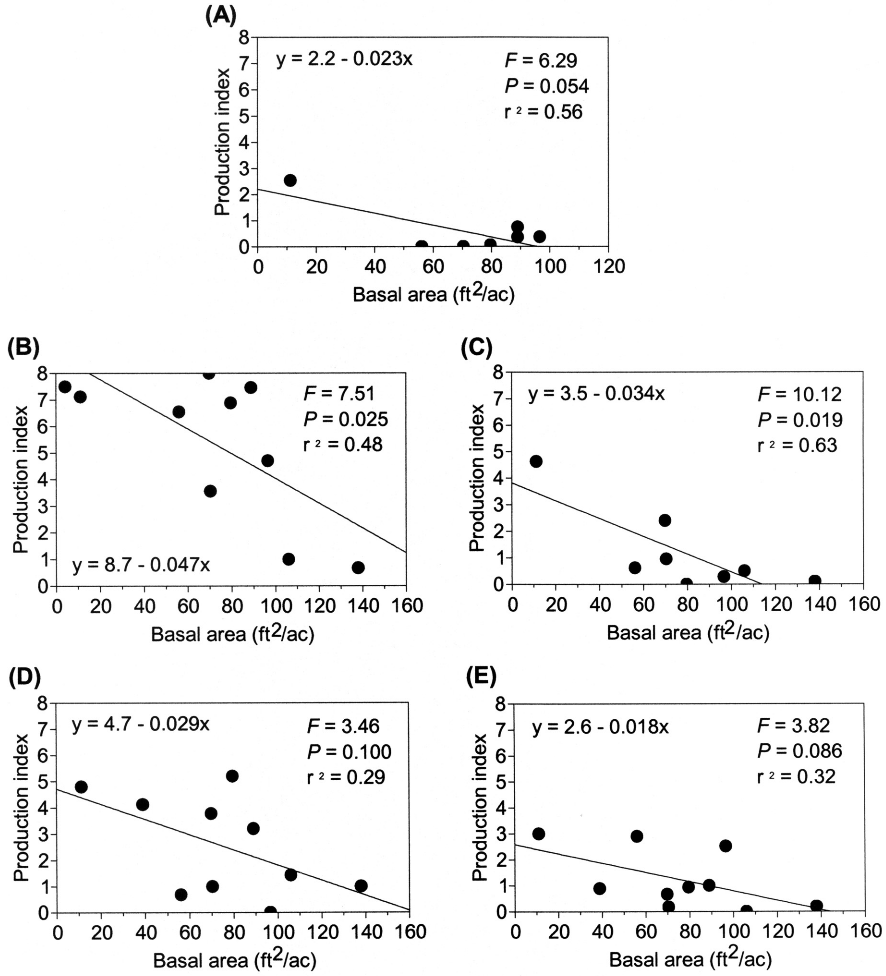

Figure 2—Yearly relationship (A = 1994, B = 1995, C = 1996, D = 1997 and E = 1998) between basal area and mean Whitehead mast production indices for post oaks (*Quercus stellata*) in the Ouachita Mountains, 1994-1998.

Hickories

A significant relationship existed between BA and hickory production indices only in 1995 and 1997 (fig. 3). No significant relationship occurred in 1994 ($F = 1.47$, $P = 0.27$, df = 1,6), 1996 ($F = 1.27$, $P = 0.29$, df = 1, 8), or 1998 ($F = 0.09$, $P = 0.78$, df = 1, 9). The relationship was strong ($r^2 = 0.79$) in 1995 (an above-average hickory-mast year) and moderate ($r^2 = 0.42$) in 1997 (also an above-average hickory-mast year). Because this relationship existed only two of the 5 sample years, the effect of stand density on hickory production is inconclusive.

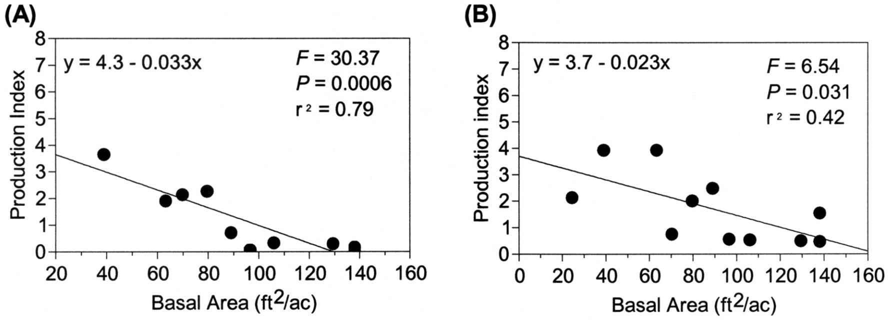

Figure 3—Yearly relationship (A = 1995, B = 1997) between basal area and mean Whitehead mast production indices for hickories (*Carya texana* and *C. tomentosa*) in 1995 and 1997 in the Ouachita Mountains. No significant linear relationship existed in 1994, 1996, or 1998 ($P > 0.10$).

CONCLUSIONS

Land managers strive to create optimal wildlife habitat by providing cover, breeding areas, and adequate resources such as food. Because hard mast is such an important food source for numerous species of wildlife, managers should consider optimizing mast production in conjunction with other management goals. Our study suggests thinning, even light thinning, can increase mast production in white and post oaks. Because these are two of the most abundant mast-producing species in pine-hardwood stands on south-facing slopes in the Ouachita Mountains, thinning should generally increase mast production of individual trees in these areas. However, we evaluated the effects only of stand density on individual trees within those stands, not the effects of thinning on overall stand production. Because thinning removes some mast-producing trees, the overall effects on stand-level production are unknown. Our results suggest production by hickories or red oaks may not benefit from thinning, but further investigation is needed to confirm this.

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