Deer Forage in Hardwood Stands following Thinning and Fertilization

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Abstract: We conducted a 10-year study in oak-hickory stands in the Arkansas Ozarks to investigate the effects of intermediate thinning and nitrogen (N) fertilization on the annual production of understory vegetation. A total of 101 experimental plots was thinned to residual overstory densities of 40%, 60%, 80%, or 100% of full stocking. Nitrogen fertilizer (336 kg N/ha) was applied to a subset of plots in each thinning treatment. Understory species composition and biomass were estimated 1, 2, 3, 5, and 10 years after treatment. Thinning and fertilizing increased ($P < 0.01$) the total biomass of understory plants and production of preferred browse species through the first 5 years after treatments. Fertilized plots thinned to 40% of full stocking produced 392 kg/ha of preferred browse, a 5-fold increase over control plots. Peak understory production occurred in the third year after thinning and the second year after fertilization. Production of total biomass and preferred browse was declining on all plots by the fifth year, as overstory canopies closed. Thinned plots continued to have significantly higher understory production through the tenth year, but fertilizer effects were not evident after the fourth year.

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Thinning and fertilizing forest stands enhances growth and yield of merchantable overstory trees in upland hardwood types (Tamm 1967; Graney and Murphy 1993, 1994). However, the effects of these practices on understory vegetation are variable and not well understood. Previous studies have shown that thinning stands with closed canopies can stimulate the development of understory vegetation, temporarily increasing the quantity and quality of forage plants used by white-tailed deer (*Odocoileus virginianus*) (Crawford 1971, Beck 1983). However, extent and duration of these effects are influenced by stand type and site quality (Murphy and Ehrenreich 1965, Crawford 1976). Research on the potential benefits of fertilizing forest stands to stimulate understory growth has been limited to pine stands. To date, no published data address these effects in hardwood stands (Harlow and Van Lear 1987).

We investigated the effects of thinning and fertilizing on understory production and production of preferred forage plants used by deer. The study was prompted by concerns of biologists and hunters whether adequate food supplies for deer could be produced on the Ozark-St. Francis National Forest in the absence of clearcutting. The range of overstory thinning represented in this study is comparable to that observed in hardwood stands regenerated by either shelterwood or selection methods. Our objectives were to (1) relate the total annual production of understory biomass to changes in overstory density and a single application of nitrogen fertilizer, and (2) assess the effects of these practices on the production of desirable browse species for white-tailed deer. Funding for the study was provided by a grant from the USDA Forest Service, Southern Forest Experiment Station, Monticello, Arkansas.

Methods

The study was conducted on 101 0.16- to 0.20-ha experimental plots established on the Ozark National Forest (ONF) in northwest Arkansas. The mountains are deeply cut into a series of steep slopes and gently sloping benches by many small streams. Elevations range from 150 m in the valleys to 700 m on the ridges. Soils are generally shallow and stony on the ridges, upper slopes, and outer bench positions. Deeper, more fertile, silt loams are found in the valleys and inner bench positions. Oak site quality is variable and is influenced by topography, soils, and aspect.

Plots were established in fully stocked, even-aged, pole-sized (12.7 to 28 cm dbh) hardwood stands that showed no evidence of recent fire or cutting. Stands were dominated by northern red oak (*Quercus rubra*), white oak (*Q. alba*), and black oak (*Q. velutina*). Site indexes for northern red oak ranged from 15 to 24.5 m at 50 years in the plots; stand age varied from 40 to 70 years. Before thinning, stand basal areas averaged 25.5 m^2/ha, and ranged from 21 to 31. These stands were selected because they were representative of the upland stands presently designated for management in the ONF.

The study was a randomized 2-factor design, with 4 levels of stocking and 2 levels of fertilization as the main effects. Each plot was surrounded by a 10-m isolation strip which received the same treatments as the plot. Thinning was conducted to produce 4 levels of residual stocking: 40%, 60%, 80%, and ≥100% of full stocking based on a tree area equation for upland oak stands (Gingrich 1967). Stocking is a relative term describing the adequacy of a given stand density in meeting maximum timber growth. It is not affected by stand structure, age, or quality. Plots were thinned from below to favor the highest quality overstory trees. Understory stems 1.5–6.0 cm dbh were reduced to 450/ha by cutting.

Thirty-five plots, distributed among stocking treatments, were fertilized once with ammonium nitrate (NH_4NO_3; 34-0-0) at the rate of 336 kg N/ha. Fertilization was conducted in late April or early May, 1 year after thinning. The remaining 66 plots, also distributed among stocking treatments, were not fertilized. Replications within each treatment cell ranged from 6 to 17 plots.

Understory vegetation was sampled in 16 quadrats systematically distributed over each treatment plot. Woody plants were sampled in 4-m^2 square quadrats. The NW quarter of each quadrat was used for sampling herbaceous plants.

Forage production of understory plants in each plot was estimated in years 1, 2, 3, 5, and 10 following treatments using double sampling (Wilm et al. 1944). Current annual growth (leaves and twigs) of woody plants to a height of 1.5 m was visually estimated by species in each quadrat. The fresh weight of each herbaceous species was estimated and recorded separately in each designated 1-m^2 quadrat. Then all annual woody and herbaceous growth was clipped in 2 randomly-selected quadrats and oven-dried at 65 C to constant weight. These data were pooled for each species, and the relationship between the actual dried weight and estimated fresh weight on the double-sampled quadrats was used to adjust estimates for the other 14 quadrats in the plot. Due to the destructive sampling of clipped plots, plots clipped one year were excluded in subsequent years. Vegetation was sampled each year between late July and mid-September.

We tested the effects of thinning and fertilization on a group of 15 locally common species of woody plants known to be preferred browse plants for deer. This group included greenbriers (*Smilax bona-nox, S. glauca, S. rotundifolia*), grapes (*Vitis rotundifolia, V. aestivalis*), sumacs (*Rhus glabra, R. copallina, R. aromatica*), poison ivy (*Toxicodendron radicans*), blackberry (*Rubus alleghenensis*), coralberry (*Symphoricarpos orbiculatus*), huckleberry (*Vaccinium vacillans*), flowering dogwood (*Cornus florida*), red maple (*Acer rubrum*), and Virginia creeper (*Parthenocissus quinquefolia*). Too little fruit was present on the plots to evaluate the production of fruits.

Two-way ANOVA was used to test for differences in understory production associated with each main effect and the interaction of thinning and fertilizing. Results from years 1, 2, 3, 5, and 10 were tested independently. ANOVA tests were conducted at the 0.05 α-level. The Tukey-Kramer studentized range procedure was used to separate means at the 0.05 α-level (SAS Inst. 1989).

Results and Discussion

Annual dry weight production of understory biomass at the initiation of thinning averaged 140.7 kg/ha (SE = 4.7). Of this total, 85% (120 kg/ha) was woody vegetation and 15% (20.7 kg/ha) was herbaceous. The annual production of understory biomass did not change in the 16 control plots during the 10-year study. Mean total production varied from 128 to 153 kg/ha among years on these plots (Fig. 1). The 15 woody species considered to be preferred deer browse comprised approximately 53% of this biomass.

Thinning increased ($P < 0.01$) the annual production of understory plants for up to 10 years after treatments (Fig. 1). In the first growing season after thinning, the annual production of woody plants was higher ($F = 12.1$; 3 df; $P < 0.001$) on thinned plots (Table 1); however, herbaceous production did not differ among thinning treatments (Table 2). Effects on woody production were directly related to the amount of overstory removed. Woody production increased by 22%, 64%, and 91% when residual overstory was reduced to 80%, 60%, and 40% of full stocking, respectively. The

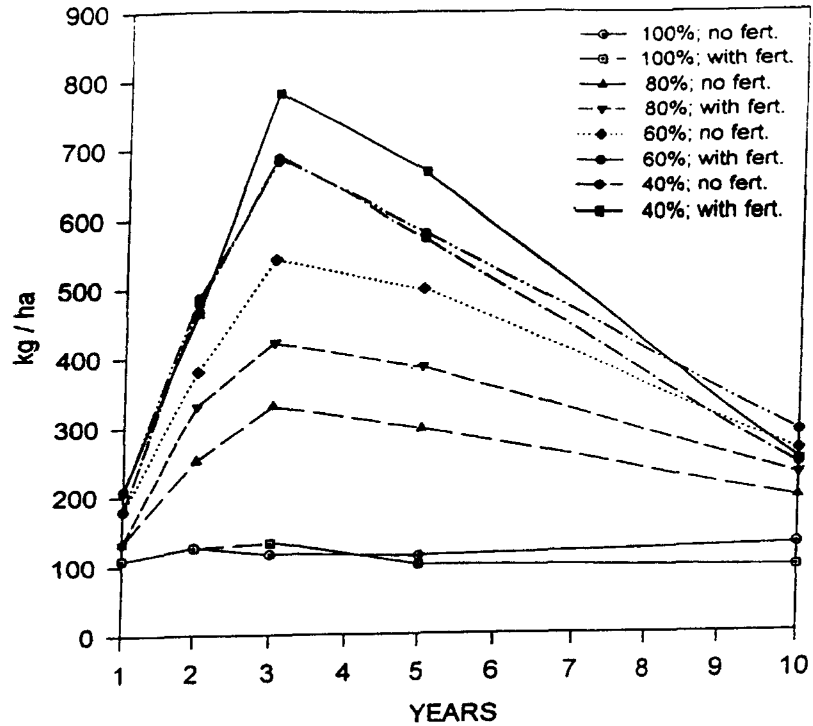

Figure 1. Total annual production of understory biomass (kg/ha) in hardwood stands in the Arkansas Ozarks. Treatments included 3 levels of overstory thinning to produce stands that were 100%, 80%, 60%, and 40% of full-stocking. Fertilized plots were treated with 336 kg N/ha.

annual production of preferred browse species also increased (F = 3.42; 3 df; P = 0.04) in thinned plots (Table 3).

Annual production of both woody and herbaceous forage continued to increase on thinned plots through the second and third years after treatments, generally peaking in the third year (Tables 1, 2). Production was highest on those plots where residual overstory had been reduced to 40% of full stocking. By the third year, nonfertilized plots thinned to 40% averaged 487% more woody browse than control plots. When residual overstory was reduced to 60% and 80%, woody browse production was 366% and 184% higher than controls, respectively, in the third year.

Annual production in all thinned plots was declining by the fifth year, and continued to fall through year 10 as canopies closed and sprouts from cut understory grew beyond the 1.5-m height accessible to deer. However, thinned plots continued to have more production (F = 21.5; 3 df; P < 0.01) than control plots in the tenth year (Fig. 1).

Overstory reductions have been shown to stimulate understory growth in pine plantations (Hurst and Warren 1982), hardwood forests (Crawford 1971, Beck 1983),

Table 1. Mean annual production of biomass (kg/ha with SE in parentheses) by woody plants in hardwood stands in the Arkansas Ozarks. Thinning was conducted to produce 4 levels of residual overstory density: 40%, 60%, 80%, and 100% of full stocking. Fertilized stands were treated with 336 kg N/ha.

		YEAR				
Treatment	*N*	1	2	3[a]	5[a]	10
100% stocked						
without N	16	109 (6)	127 (5)	116 (5)	113 (5)	128 (5)
		A[b]	A	A	A	A
with N	7	na[c]	126 (7)	132 (8)	100 (6)	94 (6)
80% stocked						
without N	16	133 (7)	251(10)	330 (16)	296 (11)	195 (6)
		A	B	B	B	B
with N	9	na[c]	331 (16)	422 (19)	385 (15)	229 (9)
60% stocked						
without N	17	179 (6)	380 (13)	541 (19)	497 (15)	263 (8)
		B	C	C	C	B,C
with N	13	na[c]	479 (18)	686 (24)	570 (21)	244 (10)
40% stocked						
without N	17	208 (8)	486 (20)	681 (25)	577 (17)	290 (13)
		B	C	C	C	C
with N	6	na[c]	464 (33)	782 (38)	664 (32)	246 (12)

[a]Fertilizer effect was significant in this year at $\alpha = 0.05$.
[b]Within each column, means followed by different letters differ significantly at $\alpha = 0.05$ due to thinning.
[c]Experimental plots were fertilized in the second year.

and mixed pine-hardwood types (Schuster 1967, Blair 1971). For example, Beck (1983) reported that thinning increased forage production in southern Appalachian hardwoods by 72% in the first year after thinning and 233% in the third year, but production declined by the fourth year. He reported that the extent and duration of this effect was directly related to the degree of thinning.

The production of preferred browse species on our plots mirrored that of other understory species, increasing through the first 3 years after thinning, then declining by the fifth year (Table 3). Unfertilized plots that were thinned to 40% produced an average of 292 kg/ha of preferred browse in the third year after thinning. This was an increase of 323% over annual production in unthinned control plots. Thinning did not affect the percentage of preferred browse species in the understory, which varied from 45% to 63% on individual plots.

Herbaceous plant production was higher in thinned plots than in control plots from the second through the fifth year (Table 2). However, this response was less dramatic than that of the woody plants due to shading from the responding woody plants. Maximum herbaceous production occurred in the third year after thinning in plots thinned to 40%. These plots averaged 56 kg/ha of herbaceous growth, nearly a 3-fold increase over control plots. The effect of thinning on the growth of herbaceous forage was more temporary than on woody species. Herbaceous production did not differ among thinning treatments in the tenth year. Blair (1971) reported that when

Table 2. Mean annual production of biomass (kg/ha with SE in parentheses) by herbaceous plants in hardwood stands in the Arkansas Ozarks. Thinning was conducted to produce 4 levels of residual overstory density: 40%, 60%, 80%, and 100% of full stocking. Fertilized stands were treated with 336 kg N/ha.

		YEAR				
Treatment	*N*	1	2	3	5	10[a]
100% stocked						
without N	16	19 (2) A[b]	20 (2) A	19 (2) A	21 (2) A	25 (3) A
with N	7	na[c]	17 (3)	9 (1)	7 (1)	8 (1)
80% stocked						
without N	16	18 (1) A	36(3) A,B	41 (5) A,B	34 (3) A,B	19 (2) A
with N	9	na[c]	20 (3)	23 (4)	17 (2)	11 (2)
60% stocked						
without N	17	20 (2) A	43 (4) B	51 (4) B,C	53 (5) C	31 (3) A
with N	13	na[c]	43 (5)	49 (7)	49 (9)	18 (3)
40% stocked						
without N	17	18 (2) A	38 (4) B	56 (7) C	45 (5) B,C	31 (5) A
with N	6	na[c]	43 (7)	79 (13)	61 (9)	22 (5)

[a]Fertilizer effect was significant in this year at $\alpha = 0.05$.
[b]Within each column, means followed by different letters differ significantly at $\alpha = 0.05$ due to thinning.
[c]Experimental plots were fertilized in the second year.

hardwoods were removed from an all-aged pine-hardwood stand in Louisiana, herbage increased for only 2 to 4 years, but browse increased for 6 to 8 years after thinning.

Plots that were fertilized produced more total understory biomass than nonfertilized plots for 4 years after treatments (Fig. 1). Fertilized plots produced 15%–30% more biomass than nonfertilized plots thinned to the same density. By the ninth year after application (Year 10), no fertilizer effects were evident. No interactions between thinning and fertilization were observed for any of the tests performed.

Several researchers have reported that fertilizing pine plantations results in a temporary increase in forage production that rarely lasts for more than 2–3 years (Hughes et al. 1971, Harlow and Van Lear 1987). Hurst et al. (1982) reported that a single application of urea (369 kg/ha) increased forage production in both thinned and unthinned pine plantations for only 12 months.

Woody understory plants responded more favorably to fertilizer application than did herbaceous vegetation (Tables 1, 2). This was contrary to observations in pine stands, where fertilization has been found to increase herbaceous understory production, but not woody plant production (Harlow and Van Lear 1987). Fertilization did not affect herbaceous production on our plots through the first 4 years after treatment; however, production was lower ($F = 8.87$; 1 df; $P < 0.01$) on fertilized plots by year 10, likely because nitrogen stimulated the growth of woody competitors.

Results of this study corroborate previous reports that overstory reduction in

Table 3. Mean annual production of browse (kg/ha with SE in parentheses) produced by 15 preferred browse species in hardwood stands in the Arkansas Ozarks. Thinning was conducted to produce 4 levels of residual overstory density: 40%, 60%, 80%, and 100% of full stocking. Fertilized stands were treated with 336 kg N/ha.

		YEAR				
Treatment	*N*	1	2	3[a]	5[a]	10
100% stocked						
without N	16	67 (4)	78 (4)	69 (3)	65 (4)	75 (5)
		A[b]	A	A	A	A
with N	7	na[c]	84 (4)	80 (5)	63 (3)	56 (4)
80% stocked						
without N	16	72 (4)	131(6)	162 (8)	150 (6)	107 (4)
		A	A,B	B	B	B
with N	9	na[c]	191 (8)	222 (10)	226 (9)	148 (6)
60% stocked						
without N	17	92 (3)	181 (8)	238 (10)	235 (8)	136 (8)
		B	B	C	C	B
with N	13	na[c]	273 (10)	363 (13)	345 (11)	158 (6)
40% stocked						
without N	17	96 (4)	220 (8)	292 (10)	280 (9)	150 (8)
		B	B	C	C	B
with N	6	na[c]	227 (10)	392 (17)	316 (12)	129 (6)

[a]Fertilizer effect was significant in this year at $\alpha = 0.05$.
[b]Within each column, means followed by different letters differ significantly at $\alpha = 0.05$ due to thinning.
[c]Experimental plots were fertilized in the second year.

oak-hickory stands significantly enhances the production of understory vegetation and forage for white-tailed deer. Woody plants responded to thinning more quickly and to a greater extent than herbaceous plants, but herbaceous production also increased for up to 5 years after thinning. Production of both woody and herbaceous forage declined after the third year. Thinning pole and sawtimber oak stands to 40%–60% of full stocking on a 10-year rotation should be a viable method of increasing forage for deer populations. However, to realize the maximum production of browse produced on our plots, it will also be necessary to treat understory stems and fertilize. These treatments could include cutting stems manually, or perhaps top-killing stems with prescribed fire.

Thinnings to enhance growth of desirable food plants should be particularly valuable on forests where stand regeneration by clearcutting or seed tree cutting is prohibited. Previous studies have shown that forage production in clearcuts in the Ozarks can vary from 180 to 360 kg/ha during the first 4 years after cutting, but declines rapidly to approximately 130 kg/ha by 10–15 after cutting, as canopies close and saplings grow above 1.5 m height (Murphy and Crawford 1970, Crawford and Harrison 1971). Harlow and Downing (1969) reported that preferred forage disappeared quickly on small clearcuts due to severe browsing and overstory competition, while large clearcuts quickly became dense and unattractive to deer. However, these authors noted that stands subjected to heavy selection cutting remained attractive to deer for longer periods because of their accessibility. Although it may be impractical to thin stands on short 10-year rotations solely to accommodate wildlife needs, this rotation might mesh well with selection system harvest rotations, thus optimizing timber regeneration and economics as well as wildlife.

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