EFFECTS OF FERTILIZATION ON THE VEGETATION DYNAMICS OF YOUNG LOBLOLLY PINE PLANTATIONS

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Abstract—We examined growth of loblolly pine (*Pinus taeda* L.) and non-pine vegetation in three 4- to 6-year-old plantations in Arkansas, Mississippi, and Louisiana that were fertilized with varying rates of N and P. Two years after treatment, pine d.b.h. growth had generally increased with fertilization rate, with significant differences in Arkansas and Mississippi. Pine height growth was more variable with no significant differences by treatment. Significant differences in leaf area index were observed in Mississippi and Louisiana. At two sites, non-pine woody biomass was significantly greater at higher fertilization rates. However, there were no significant differences in total biomass of non-pine vegetation at any of the study areas. The limited differences between treatments may be due to drought, an ice storm, the short-term nature of our study, an insufficient number of biomass plots, and/or crown closure at one of the study sites.

INTRODUCTION

Midrotation fertilization of loblolly pine (*Pinus taeda* L.) plantations has become a common silvicultural practice throughout the Southern United States. Field trials established by the North Carolina State Forest Nutrition Cooperative (NCSFNC 1997,1998), as well as growth and yield models developed from fertilized midrotation stands (Amateis and others 2000, Hynynen and others 1998), indicate that midrotation pine plantations are responsive to single applications of nitrogen (N) and phosphorus (P). As a result, over 280,000 ha of established pine plantations were fertilized in 2001 with 224 kg per ha N and 28 kg per ha P (NCSFNC 2002a). This prescription has proven ecologically and economically attractive to the forest industry; over the next 8 years, this $50 million investment in fertilization is predicted to result in an increase in wood yield of almost 27,000 kg per ha.

Given the successful application of midrotation treatments, research activities have expanded to include fertilizing earlier in the rotation. For example, the most recently established NCSFNC field trial, Regionwide (RW) 18, is designed to identify optimal rates and frequencies of fertilization in relatively young (3- to 7-year-old) pine plantations (NCSFNC 2000, 2001, 2002b). Consequently, treatments in RW 18 stands generally begin before or at time of canopy closure and include previously untested fertilizer rates and frequencies.

From a silvicultural perspective, the RW 18 field trial is a novel approach because it examines fertilization as a treatment to be applied throughout a rotation. However, one limitation of the study is the use of pine trees as the sole vegetative indicator of response to fertilization. Understandably, pine growth is of paramount interest to the industrial forest manager. Yet the response of non-pine vegetation, ranging from hardwood trees and shrubs to herbaceous plants, is important for several reasons. First, this vegetation is potentially competitive with pine for available resources. Theoretically, large increases in non-pine biomass due to fertilization may at some point negatively influence pine growth. Second, the quality and quantity of non-pine vegetation are important determinants of wildlife habitat. For example, different fertilization regimes may create uniquely different sets of understory and ground cover structural characteristics. Finally, non-pine vegetation is the chief source of plant diversity in plantations. Such vegetation is important for enhancing stand-level biodiversity within intensively managed pine forests.

This study describes the 2-year responses of pines and non-pine vegetation to different fertilization rates at three RW 18 sites in Arkansas, Mississippi, and Louisiana. Although RW 18 was designed as a rate and frequency experiment, the sites we selected were not fertilized a second time until after our study was completed. Therefore, we did not examine the effects of varying fertilization frequencies on plant growth.

METHODS

Study Sites

The three NCSFNC RW 18 field sites chosen for this study were 4- to 6-year-old loblolly pine plantations in the Upper Coastal Plain. The sites were located: (1) south of Warren, AR on land owned by Potlatch Corporation; (2) north of Meridian, MS on land owned by Plum Creek; and (3) north of Leesville, LA on land owned by Boise. All sites were fertilized by hand in the winter of 1999-2000. Each installation had two replications of five treatments: 0 kg per ha N and 0 kg per ha P, 67 kg per ha N and 7 kg per ha P, 134 kg per ha N and 13 kg per ha P, 202 kg per ha N and 20 kg per ha P, and 269 kg per ha N and 27 kg per ha P. Each study site contained 10 plots that averaged 0.04 ha in size. The plots at each site were blocked to minimize pretreatment variation in volume, basal area, total height, and density of the planted pines. An analysis of variance indicated no significant pretreatment differences ($\alpha = 0.05$) in these parameters at any site.

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Table 1—Pre-treatment characteristics at the three study sites

	Arkansas	Mississippi	Louisiana
Pine age (*years*)	4	4	6
Pine density (*trees per ha*)	1,255	1,630	1,775
Mean pine d.b.h. (*cm*)	5.8	5.1	7.6
Mean pine height (*m*)	3.8	4.0	5.9
Mean pine basal area (*m*^{2} *per ha*)	3.0	5.7	8.3
Soil series	Stough	Smithdale	Sacul
Soil texture	Fine sandy loam	Fine sandy loam	Sandy loam

Pine Measurements

Pine trees were measured at each study area during the winter of 1999-2000 (pretreatment), 2000-2001 (after 1 growing season), and 2001-2002 (after 2 growing seasons). Measurements included d.b.h. and total height; heights were measured with a height pole or hypsometer. In September 2001, pine leaf area index (LAI) in each plot was measured with a LI-COR LAI-2000 canopy analyzer (LI-COR Incorporated, Lincoln, Nebraska). LAI measurements were taken during the first and second week of September, which is the period of maximum LAI for loblolly pine in the South (Sampson and Allen 1999).

Non-Pine Biomass Measurements

In August 2001 (i.e., near the end of the second growing season after fertilization), two 1-m^2 biomass plots were systematically established in each treatment plot to sample non-pine vegetation. With 2 replicates per treatment, there were a total of 20 biomass plots per study site. All living vegetation rooted within each 1-m^2 plot was hand clipped at ground level. Plants were categorized by one of three vegetation types: grasses, sedges, and rushes; forbs; or woody stems. Samples were taken to a laboratory at the University of Arkansas-Monticello and oven dried at 60 °C for 48 hours. After the samples dried, they were weighed to determine oven-dry biomass.

Data Analysis

For pine d.b.h., pine total height, pine LAI, and non-pine biomass 2 years after fertilization, a complete randomized design (CRD) was used to test for differences among the treatments at each site using $\alpha = 0.05$. Data were analyzed with the general linear model (PROC GLM) of the Statistical Analysis System (SAS Institute Inc. 1989). Tukey's multiple range test (α=0.05) identified statistical groupings when a significant difference was detected through the GLM procedures.

RESULTS AND DISCUSSION

The pre-treatment characteristics of each study area are listed in table 1. The Louisiana stand was the oldest (6 years) and had the greatest pine density, the largest mean pine d.b.h. and height, and the highest pine basal area. The Arkansas and Mississippi sites were the same age (4 years); the Arkansas site had the lowest pine stem density, mean pine height, and pine basal area.

Two years after fertilization, pine d.b.h. at all three sites generally increased with increasing fertilization rates (table 2). Significant differences were observed in the Arkansas and Mississippi plantations. In Arkansas, mean 2-year d.b.h. growth ranged from 4.9 cm in the untreated control to 6.1 cm in the 269 kg per ha N treatment. In Mississippi, mean d.b.h. growth varied from 4.4 to 5.6 cm. Mean diameter growth was lowest at the Louisiana site and ranged from 2.8 to 3.2 cm after 2 years. These results are consistent with those from other RW 18 installations in the

Table 2—Mean d.b.h. growth, height growth, and leaf area index 2 years after fertilization for loblolly pine trees at the three study sites[a]

Treatment	D.b.h. growth	Height growth	LAI
kg N per ha	*cm*	*m*	
	Arkansas		
0	4.9a	2.1a	2.1a
67	5.3ab	2.1a	2.0a
134	5.6ab	1.9a	2.2a
202	5.9b	1.9a	2.5a
269	6.1b	1.8a	2.2a
	Mississippi		
0	4.4a	2.7a	2.2a
67	4.9ab	2.7a	2.1a
134	5.4ab	2.8a	2.2a
202	5.4ab	2.7a	2.3a
269	5.6b	2.7a	2.6b
	Louisiana		
0	2.8a	2.0a	2.2a
67	2.8a	2.1a	2.3a
134	3.0a	2.0a	2.6b
202	3.0a	2.0a	2.7bc
269	3.2a	2.0a	2.9c

LAI = leaf area index.
[a] For a given site, column means followed by the same letter are not significantly different at α = 0.05.

Southern United States. Of the 13 sites not examined in our study, 11 showed significant positive d.b.h. growth responses 2 years after fertilization (NCSFNC 2002b). In addition, Haines and Haines (1979) reported a significant increase in pine d.b.h. growth 2 years after fertilizing a 4-year-old loblolly pine plantation in North Carolina.

Two-year pine height growth response to fertilization was variable and did not significantly differ by treatment at the study areas (table 2). In Arkansas, a severe ice storm in December 2000 damaged the crowns of many pines, particularly those that received higher rates of fertilization. In fact, 2-year height growth was lowest (1.8 m) in the 269 kg per ha N treatment and highest (2.1 m) in the control and 67 kg per ha N plots. In Mississippi, mean height growth ranged from 2.7 to 2.8 m. Similar to d.b.h. growth, mean height response was lowest at the Louisiana stand and varied from 2.0 to 2.1 m. That pine height growth was less sensitive to fertilization than d.b.h. appeared to be a regional phenomenon. Among the RW 18 stands, only 6 of the other 13 sites reported significant height growth responses 2 years after fertilization (NCSFNC 2002b).

There were no significant differences in pine LAI by treatment in Arkansas 2 years after fertilization (table 2). At this site, LAI ranged from 2.0 to 2.5. In Mississippi, the 269 kg per ha N plots had a significantly higher LAI (2.6) than the other treatments, in which LAI ranged from 2.1 to 2.3. Only at the Louisiana plantation was there a pattern of significantly higher LAI with increasing fertilization rate. LAI ranged from 2.2 in the control to 2.9 in the 269 kg per ha N treatment.

There were no significant differences by treatment for grass biomass, forb biomass, and total biomass at any of the sites (table 3). Woody biomass was significantly greater in the 269 kg per ha N plots in Arkansas and Mississippi, but not in Louisiana. Total biomass values for all treatments in Louisiana were far below those at the other sites, primarily because of a sparse woody understory component. The overall muted understory biomass response to fertilization contrasts with a number of other studies in loblolly pine plantations. For example, Brockway and others (1998) and Wolters and others (1995) reported significant increases in herbaceous plant production for the first 3 years after time of planting fertilization in sites throughout the West Gulf Coastal Plain. In Louisiana, Tiarks and Haywood (1986) found that significant increases in herbaceous biomass were maintained for 4 years after time of planting fertilization. Also in Louisiana, Haywood and Thill (1995) observed significant increases in herbaceous production 1 and 2 years after time of planting fertilization. In North Carolina, Haines and Haines (1979) reported a 30 percent increase in ground cover biomass 2 years after fertilizing a 4-year-old plantation. Such increases in understory plant biomass appear to be short-term gains that are generally not maintained for longer than 5 years (Brockway and others 1998, Tiarks and Haywood 1986, White 1977, Wolters and

Table 3—Mean non-pine biomass (g per m^2) by treatment 2 years after fertilization at the three study sites[a]

Treatment	Grasses,sedges and rushes	Forbs	Woody stems	Total
(*kg N per ha*)				
		Arkansas		
0	30.0a	15.0a	49.8ab	94.8a
67	26.4a	23.0a	18.1a	67.5a
134	18.6a	6.0a	120.2ab	144.7a
202	46.4a	9.6a	78.2ab	134.2a
269	11.1a	16.0a	124.6b	151.7a
		Mississippi		
0	24.7a	7.4a	159.6a	191.7a
67	39.1a	17.9a	209.2ab	266.2a
134	22.8a	47.9a	162.7ab	233.4a
202	38.1a	14.1a	114.7a	166.9a
269	12.8a	33.1a	278.1b	324.0a
		Louisiana		
0	39.7a	1.0a	28.5a	69.2a
67	25.7a	4.5a	10.0a	40.2a
134	51.4a	1.0a	9.1a	61.5a
202	42.9a	1.3a	17.3a	61.5a
269	11.4a	1.7a	14.2a	27.2a

[a] For a given site, column means followed by the same letter are not significantly different at $\alpha = 0.05$.

Schmidtling 1975, Wolters and others 1995), probably because closure of the pine canopy reduces understory production.

CONCLUSIONS

The response of pines and non-pine vegetation in this study was less than we anticipated. Overall, there was not a consistent pattern of significantly increased growth with increasing fertilizer rate. The limited number of differences between treatments may be explained by a number of potential factors. First, climatic events probably negatively affected plant growth during part of the study period. For example, drought conditions existed at all three study areas in 1999 and 2000; growing season precipitation during these years was far below normal (Agricultural Weather Information Services, Auburn, AL). In addition, the December 2000 ice storm broke the tops of many pine trees at the Arkansas site. Second, this study examined short-term (2 years) responses to fertilization. Perhaps this was too limited a time period for biological patterns to emerge, particularly for pine trees. Third, our biomass sampling intensity may not have been adequate. We established only two 1-m^2 biomass plots in each treatment plot at each site. Field observations at the Arkansas and Mississippi sites 2 years after fertilization indicated greater understory biomass in the more heavily fertilized plots. That these differences were not detected in our data suggest that greater sampling intensity may have been warranted. Finally, pine d.b.h. and non-pine biomass response to fertilization in Louisiana were probably influenced by the pine canopy. The Louisiana plantation was 2 years older than the stands in Arkansas and Mississippi and, in contrast with these sites, had a distinctly closed canopy. The resulting overstory competition and shaded conditions likely inhibited pine d.b.h. growth and the development of a productive understory community regardless of fertilization treatment.

Because of any or all of the aforementioned reasons, results from this study remain inconclusive. Continued measurements from the treatment plots are needed to describe more clearly the effects of fertilization on pines and non-pine vegetation in young loblolly pine plantations. Long-term results from RW 18 sites throughout the South will help determine whether fertilizing young pine stands, like midrotation fertilization, becomes an operational silvicultural practice.

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LITERATURE CITED

Amateis, R.L.; Liu, J.; Ducey, M.J. [and others]. 2000. Modeling response to midrotation nitrogen and phosphorus fertilization in loblolly pine plantations. Southern Journal of Applied Forestry. 24: 207-212.

Brockway, D.G.; Wolters, G.L.; Pearson, H.A. [and others]. 1998. Understory plant response to site preparation and fertilization of loblolly and shortleaf pine forests. Journal of Range Management. 51: 47-54.

Haines, L.W.; Haines, S.G. 1979. Fertilization increases growth of loblolly pine and ground cover vegetation on a Cecil soil. Forest Science. 25: 169-174.

Haywood, J.D.; Thill, R.E. 1995. Long-term responses of understory vegetation on a highly erosive Louisiana soil to fertilization. Res. Note SO-382, Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 6 p.

Hynynen, J.; Burkhart, H.E.; Allen, H.L. 1998. Modeling tree growth in fertilized midrotation loblolly pine plantations. Forest Ecology and Management. 107: 213-229.

North Carolina State Forest Nutrition Cooperative. 1997. Ten-year growth and foliar responses of midrotation loblolly pine plantations to nitrogen and phosphorus fertilization. NCSFNC Report Number 39. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 116 p.

North Carolina State Forest Nutrition Cooperative. 1998. Growth and foliar nutrient responses of midrotation loblolly pine to nitrogen, phosphorus, and potassium fertilization. NCSFNC Report Number 41. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 124 p.

North Carolina State Forest Nutrition Cooperative. 2000. Identifying optimal rates and frequencies of nutrient additions to maintain high rates of plantation production: Regionwide 18 first report. NCSFNC Report Number 43. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 18 p.

North Carolina State Forest Nutrition Cooperative. 2001. Responses to nutrient additions in young loblolly pine plantations: Regionwide 18 second report. NCSFNC Report Number 46. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 19 p.

North Carolina State Forest Nutrition Cooperative. 2002a. Thirty-first annual report. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 21 p.

North Carolina State Forest Nutrition Cooperative. 2002b. Responses to nutrient additions in young loblolly pine plantations: Regionwide 18 third report. NCSFNC Report Number 49. Raleigh, NC: Forest Nutrition Cooperative, Department of Forestry, College of Forest Resources, North Carolina State University. 22 p.

Sampson, D.A.; Allen, H.L. 1999. Regional influences of soil available water-holding capacity and climate, and leaf area index on simulated loblolly pine productivity. Forest Ecology and Management. 124: 1-12.

SAS Institute Inc. 1989. SAS/STAT user's guide. version 6. ed. 1, vol. 1. Cary, NC: SAS Institute Inc. 943 p.

Tiarks, A.E.; Haywood, J.D. 1986. *Pinus taeda* L. response to fertilization, herbaceous plant control, and woody plant control. Forest Ecology and Management. 14: 103-112.

White, L.D. 1977. Forage production in a five-year-old fertilized slash pine plantation. Journal of Range Management. 30: 131-134.

Wolters, G.L; Schmidtling, R.C. 1975. Browse and herbage in intensively managed pine plantations. Journal of Wildlife Management. 39: 557-562.

Wolters, G.L.; Pearson, H.A.; Thill, R.E. [and others]. 1995. Response of competing vegetation to site preparation on West Gulf Coastal Plain commercial forest land. Gen. Tech. Rep. SO-116. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 8 p.