GROWTH OF PRECOMMERCIALLY THINNED LOBLOLLY PINE 4 YEARS FOLLOWING APPLICATION OF POULTRY LITTER

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Abstract—Application of poultry litter to southern pine stands represents a potentially attractive litter disposal option. Many pine stands are nutrient-limited and might respond positively to the added nutrients. However, the ability of pine stands to respond to nutrients contained in the litter, as well as contain the nutrients on site, has not been thoroughly investigated. We applied poultry litter to a recently-thinned 8-year-old loblolly pine (Pinus taeda L.) stand at 0, 5.6, and 23 Mg ha^{-1} (dry-weight basis), supplying 0, 200, and 800 kg N ha^{-1}. Growth was tracked for four growing seasons following application. Average height growth was generally unaffected by treatments over the 4-year period. Diameter, basal area, and total cubic volume increments were all elevated by the litter application over the first three growing seasons, but annual increments in all treatments dropped substantially in year 4. Total basal area and standing volume at end of year 4 were significantly greater in the N_{200} and N_{800} treatments.

INTRODUCTION

Disposal of waste materials generated in confined animal feeding operations is becoming an increasing problem. In the Southeastern United States, poultry production is one of the region's major agricultural activities, raising nearly 6.6 billion broiler chickens annually with a production value of over $11.7 billion (U.S. Department of Agriculture 2004). Production is concentrated in densely populated chicken houses, resulting in large amounts of litter. In 1998, an estimated 12 million mt of poultry litter was produced nationally (Endale and others 2002).

Historically, the primary disposal mechanism for litter generated in poultry production has been application to pastureland as an organic fertilizer (Endale and others 2002, Sauer and others 1999). Years of repeated applications, however, have elevated soil nutrient levels, particularly phosphorus, to the point of concern over potential effects of nutrient-rich runoff on water quality (Sauer and others 1999, Sims and Wolf 1994).

An alternative to pasture application could be the abundant pine forests of the South (Beem and others 1998, Roberts and others 2004, Samuelson and others 1999). Many southern pine stands are nutrient-limited and respond positively to added nutrients (Allen and others 1990). However, the ability of pine stands to contain the nutrients added in poultry litter and respond to those nutrients with added growth has not been investigated thoroughly.

This study was initiated to investigate (1) the ability of pine stands to contain nutrients applied in poultry litter on the site, and (2) the ability of trees to respond to the nutrients contained in the poultry litter. This paper reports on the growth over four seasons following poultry litter application to a precommercially-thinned 9-year-old loblolly pine (Pinus taeda L.) stand in central Mississippi.

METHODS

The study was located in Newton County, MS, on the Mississippi State University Coastal Plain Branch Experiment Station (32º20'N, 89º04'W). Average annual daily high and low temperatures at the site are approximately 24 °C and 11 °C, respectively. Average annual precipitation is approximately 1,400 mm. Soils on the study site are a fine sandy loam in the Shubuta Series, classified as a fine, mixed, thermic Typic Paleudults. Treatments were implemented in an 8-year-old loblolly pine stand that initiated as a plantation following clearcut harvest but, due to heavy natural regeneration, contained over 4,000 trees ha-1 (table 1).

Nine 20-m x 20-m treatment plots were established and thinned to a basal area of approximately 11 m^2 ha^{-1}. Within each treatment plot, a 10-m x 10-m measurement plot was established containing between 27 and 56 trees. In March, 2000, poultry litter in the form of stock-piled cake collected from a local broiler operation near Newton, MS, was applied to the plots. At the time of application, litter moisture content was 21 percent . The elemental composition of the litter on a dry-weight basis was 380 g kg^{-1} C, 43 g kg^{-1} N, 20 g kg^{-1} P, 32 g kg^{-1} K, 28 g kg^{-1} Ca, 7 g kg^{-1} Mg, 6 g kg^{-1} S, 590 mg kg^{-1} Zn, 60 mg kg^{-1} B, 680 mg kg^{-1} Mn, 987 mg kg^{-1} Fe, and 969 mg kg^{-1} Cu. Beginning in May, 2000, understory vegetation was controlled annually with herbicides.

Table 1—Pretreatment stand conditions for each of three poultry litter application treatments. No significant treatment differences existed between any of the variables

	Treatment		
	N_0	N_{200}	N_{800}
Stem density (trees ha^{-1})	4,267	4,067	3,433
Reineke's stand density index	397	394	391
Mean height (m)	6.4	6.6	7.0
Quadratic mean diameter (cm)	5.9	6.2	6.7
Basal area (m^2 ha^{-1})	11.3	11.4	11.7
Total cubic volume (m^3 ha^{-1})	24.6	26.5	29.1

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Litter was applied at three treatment rates to three plots per treatment in a completely randomized design. The three treatment rates were 0 Mg ha^{-1} (N_0 = Control), 5.6 Mg ha^{-1} (N_{200}), and 23 Mg ha^{-1} (N_{800}). Application rates were based on the N assay of the litter to supply approximately 0, 200, and 800 kg N ha^{-1}, respectively. The N_{200} treatment was designed to add N at approximately the same rate as would typically be applied in an operational commercial fertilization. This resulted in adding approximately 2 to 3 times more P than would typically be applied operationally. The three treatments resulted in P applications of approximately 0, 92, and 370 kg ha^{-1}.

Trees on each measurement plot were measured pretreatment, and bi-monthly thereafter, for stem diameter at breast height (d.b.h., 1.37 m) and total height. Basal area (m^2) was calculated for each tree. Total volume inside bark (m^3) was computed using the equation of Baldwin and Feduccia (1987) for thinned loblolly pine stands.

Analysis of variance using a general linear models procedure was used to test for treatment differences in annual plot mean tree increments for height and diameter, and annual increments in plot-level basal area and total cubic stem volume. Also tested for after 4 years were treatment differences in plot mean tree size, basal area, and volume. Determinations of significant treatment differences were made using Tukey's LSD test with a critical value of α=0.05.

RESULTS

Annual height increments did not differ among treatments during the first 3 years following treatment (fig. 1a). In year 4, height growth of all three treatments differed, with treatment N_{800} having the greatest height increment and N_0 having the lowest increment. Height increments in year 4, however, only ranged from 0.2 to 0.4 m, compared to increments of 0.7 to 1.0 m in the previous years. The cumulative height increment over the 4-year period following treatment did not differ by treatment. Average height after year 4 also did not differ by treatment (table 2, fig. 2a).

Average annual diameter growth in each of the two growing seasons following treatment was greater on the plots receiving litter than on the N_0 plots (fig. 1b). Diameter increment did not differ between the N_{800} and N_{200} treatments over the first 2 years. In year 3, diameter growth on the N_{800} plots remained significantly higher than both the N_{200} and N_0 plots. In year 4, there were no significant treatment differences in diameter increment. Over the entire 4-year period, diameter growth on the N_{800} and N_{200} plots was higher than on the N_0 plots. Total 4-year diameter increments were: N_{800} = 4.3 cm, N_{200} = 3.8 cm, and N_0 = 2.6 cm. Despite significant treatment differences in annual diameter increments, there were no significant treatment differences in quadratic mean diameter at the end of 4 years (table 2, fig. 2b), even though quadratic mean diameter on the N_{800} plots (11.0 cm) was, on average, 1.0 cm

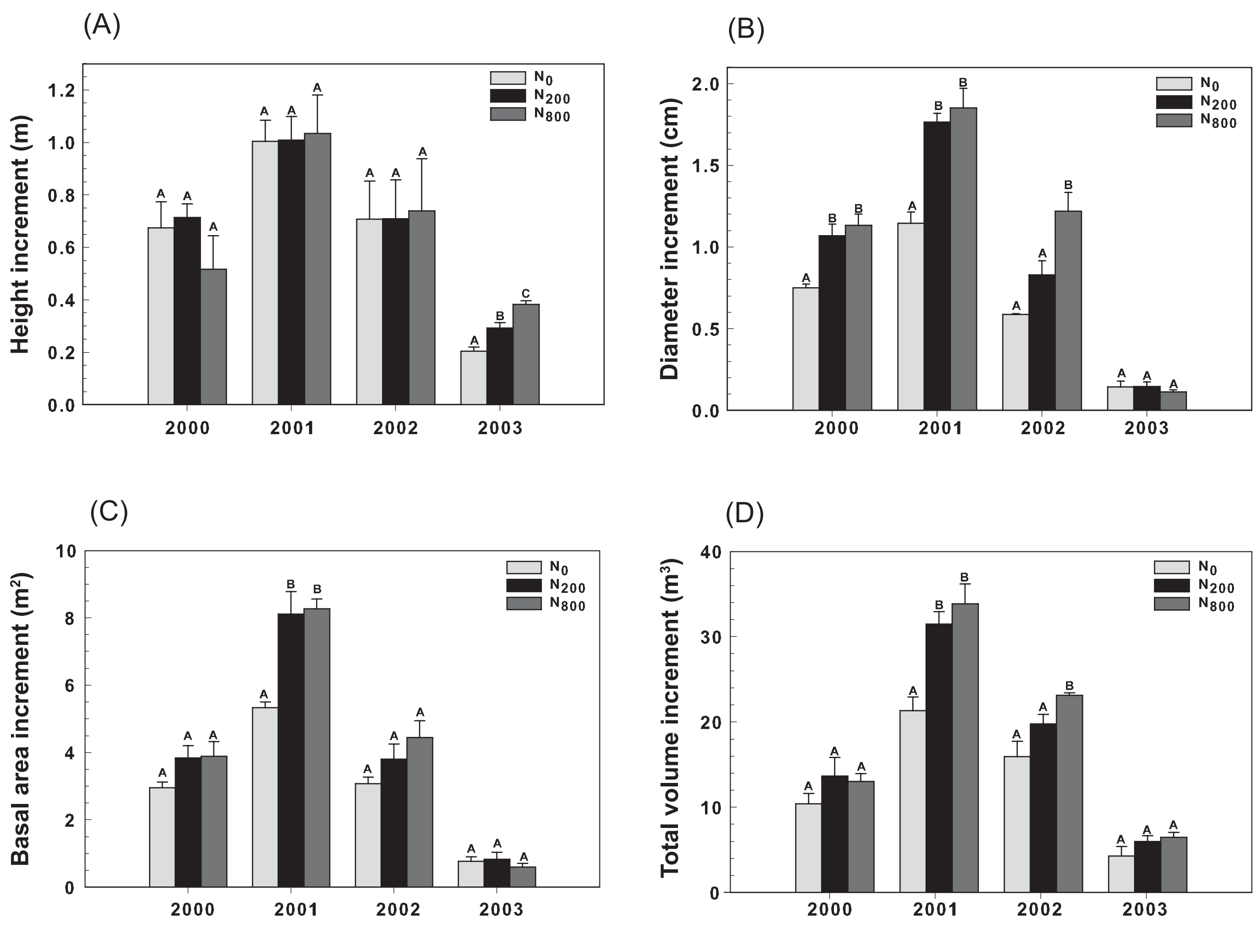

Figure 1—Annual growth increments in (A) mean height, (B) mean diameter, (C) basal area per hectare, and (D) total cubic volume per hectare. Similar letters among treatments within a given year indicate no significant treatment effect according to Tukey's LSD test (α = 0.05).

Table 2—Stand conditions for each of three poultry litter treatments 4 years following application. Similar letters or no letters among treatments indicate no significant treatment effects according to Tukey's LSD test (α = 0.05)

	Treatment		
	N_0	N_{200}	N_{800}
Stem density (trees ha^{-1})	4,233	3,733	3,133
Reineke's stand density index	717	809	803
Mean height (m)	9.0	9.3	9.7
Quadratic mean diameter (cm)	8.6	10.0	11.0
Basal area (m^2 ha^{-1})	23.5a	28.0b	28.9b
Total cubic volume (m^3 ha^{-1})	76.5a	97.4a	105.6b

greater than on the N_{200} plots (10.0 cm) and 2.4 cm greater than on the N_0 plots.

There were no significant treatment differences in annual basal area increment in the first year following litter application (fig. 1c), nor were there significant differences in years 3 and 4. Year 2 was the only year in which treatment differences occurred, with N_{800} and N_{200} both significantly greater than N_0 but not different from each other. Over the 4-year period following treatment, the average cumulative basal area increments on the N_{800} plots (17.2 m^2 ha^{-1}) and N_{200} plots (16.6 m^2 ha^{-1}) were significantly greater than on the N_0 plots (12.1 m^2 ha^{-1}). Total basal area at the end of year 4 on the N_{800} plots (28.6 m^2 ha^{-1}) and N_{200} plots (28.0 m^2 ha^{-1}) were significantly greater than on the N_0 plots (23.5 m^2 ha^{-1}) (table 2, fig. 2c).

Volume increments did not differ among treatments in the first year following litter application (fig. 1d). In year 2, average volume growth on both the N_{800} and N_{200} treatments was significantly greater than on the N_0 plots. In year 3, volume growth on the N_{800} plots remained greater than both of the other treatments. In year 4, there were once again no treatment differences in volume increment. Over the 4-year period, the cumulative volume increments on the N_{800} (76.5 m^3 ha^{-1}) and N_{200} (70.9 m^3 ha^{-1}) plots were significantly greater than on the N_{200} plots (51.9 m^3 ha^{-1}). Total standing volume at the end of the 4-year period on the N_{800} plots (105.6 m^3 ha^{-1}) was significantly greater than on the N_{200} (97.4 m^3 ha^{-1}) and N_0 (76.5 m^3 ha^{-1}) plots (table 2, fig. 2d).

DISCUSSION

Tree and stand growth responded positively to the treatments. Some of this growth response was likely caused by the thinning that took place prior to application of the poultry litter, as indicated by the growth increase that occurred on the N_0 plots. The addition of nutrients in the litter, however, clearly had a positive effect on growth.

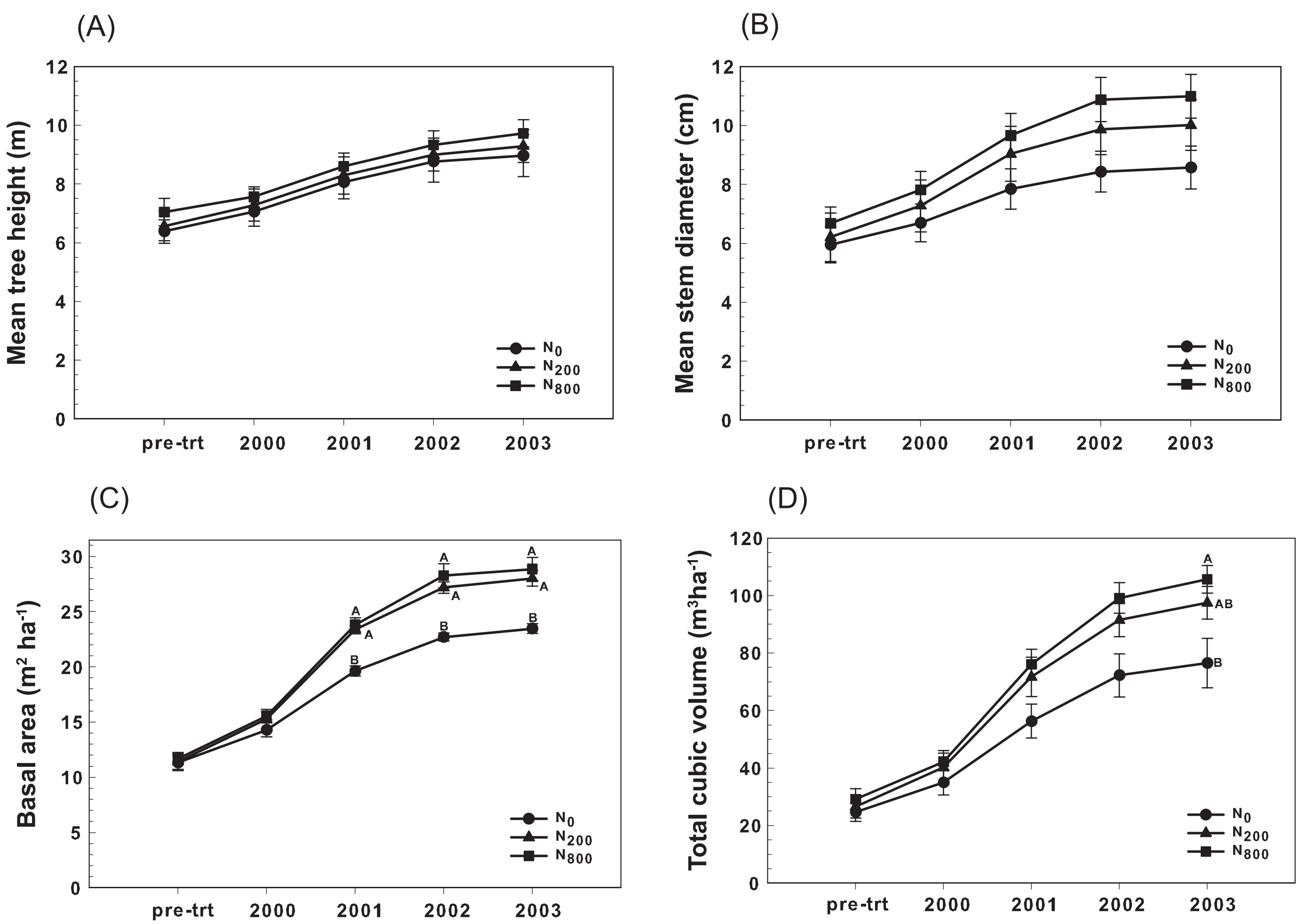

Figure 2—Change in treatment mean values for (A) height, (B) diameter, (C) basal area, and (D) total cubic volume over 4 years following poultry litter application. Similar letters or no letters among treatments indicate no significant treatment effects according to Tukey's LSD test (α = 0.05).

A significant increase in diameter increment occurred as early as the first growing season following litter application in both the N_{200} and N_{800} treatments. The greatest growth increases, however, occurred in the second growing season where diameter, basal area, and volume increments were all greater on the treated plots than on plots not receiving litter. Diameter increments in year 2 were, on average, 54 to 61 percent higher on the treated plots. Basal area increments were 52 to 55 percent higher, and volume increments were 48 to 59 percent higher.

Treatment effects started to dissipate by the third year. Growth increments on the N_{200} treatment, while still slightly higher on average, were no longer significantly different from the N_0 plots. Annual increments on the N_{800} plots remained significantly elevated for diameter and volume growth but not for basal area growth. Overall, the annual growth increments in year 3 were similar to the growth increments in year 1.

There were no significant treatment differences in year 4 for diameter, basal area, or volume increment. For some reason, however, annual height increment did show a significant treatment effect, although the differences in height increment were rather small. Growth increments of all measures showed sharp decreases in year 4, dropping to levels well below those exhibited in year 1. Some of these decreases make sense, while others are difficult to explain. The decrease in diameter growth, for example, was likely the result of all of the plots having reached relatively high levels of growing stock. Reineke's stand density index (SDI) on the N_0 plots averaged nearly 64 percent of the reported maximum for loblolly pine (table 2). On the N_{200} and N_{800} plots, SDI averaged nearly 72 percent of maximum. Individual tree growth at these levels of stocking would be expected to be relatively low.

Reasons for decreases in basal area and volume increment are a bit more elusive. Although increments in basal area would be expected to decline eventually, the basal area of these stands at the end of year 4 (approximately 28 m^2 ha^{-1} on the plots receiving litter) are not so high that increments should be greatly reduced. Total cubic volume growth, particularly in the absence of self-thinning, should remain high given the levels of growing stock on these plots. Height increment, which should be rather insensitive to stand density, also showed a sharp decline in year 4. While there were small treatment differences, the average height growth increment across all nine plots was < 0.3 m. This is much lower than would be expected in a 12-year-old loblolly pine stand, particularly one that had recently been thinned and, in the case of the N_{200} and N_{800} plots, had added nutrients.

The sharp decrease in growth increments in year 4 cannot be explained by annual weather conditions. In 2003, precipitation at the study site was nearly 360 mm above average, much of that occurring in June and July. By comparison, the year 2000 (year 1 of the study) was the last in a series of years with below-average rainfall, and precipitation at the study site in that year was nearly 350 mm below normal.

The year 4 declines in growth increment appear to have been due to the weakening of both the thinning effect and the treatment effect. The plots were thinned to about 35 percent of maximum SDI, and they have now reached levels of growing stock where the thinning is probably no longer having substantial affects on tree growth. Unfortunately, we do not have growth increment data pretreatment or from an unthinned control to compare with the year 4 increments.

The growth benefits of the added poultry litter appear to have been rather short-lived on these sites. By the end of the fourth growing season soil, foliar, and forest floor P levels on the treated plots remain slightly elevated, although there were few treatment differences in the levels of other nutrients (data not shown). However, while most nutrient levels were no longer elevated, results from past fertilization studies would suggest that growth responses to the added nutrients should last more than 3 years (Allen 1987, Hynynen and others 1998). Future measurements will determine whether the treatment effect in fact only lasted for 3 years or whether the year-4 declines in growth were anomalous.

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