NC STATE UNIVERSITY
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Late-Rotation Nitrogen Management in Deciduous Short Rotation Woody Crops

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Introduction

Idle cropland is a potentially significant resource for producing woody crops as an energy or chemical feedstock. Short rotation woody crops [SRWC] may offer an opportunity to improve soil health, water quality, and to sequester soil carbon (C). Understanding the processes controlling the nutrient cycles is fundamental to developing management practices to ensure long-term soil productivity while protecting or enhancing environmental quality.

Nutrient management is essential to SRWC systems, as most sites are nutrient limited, usually by nitrogen (N), and supplementation is necessary to achieve commercially viable yields. The focus of most fertilization trials with plantation hardwoods (e.g., sweetgum, sycamore, and cottowood) in the southern US has been during the establishment and early development stages (1-6 yrs) of the plantation. While those studies typically show a productivity response to N additions, it is uncertain what effects mid-rotation fertilization practices would have on productivity responses and the environment in the Southeast. Nitrogen demands are greatest following canopy closure in hardwood plantations (e.g., typically 4-7 yrs); hence, managing the N supply in the mid-rotation period may be critical to sustaining high levels of productivity. Work in Mississippi demonstrated that the fertilization response can be significant (Nelson and Switzer, 1992; Nelson et al., 1995). To satisfy the N demand and realize productivity potential, N must be supplied from the soil, internal translocation, and fertilizer inputs. Determining the site and stand constraints on the sources of N and the efficiencies of nutrient utilization are fundamental to sustainable management prescriptions for SRWC (Coyle and Coleman, 2005). The experiment was designed to test both rate and frequency of fertilizer application. To test for the affects of timing (Van Miegrot et al., 1994), a single application versus bi-annual applications were also evaluated. The N fertilization rates were designed to test a recent recommendation of 50 kg N ha^{-1} per 2000 kg foliage biomass (Scott et al., 2004).

Objective

Develop the basis for managing nutrient availability in mid-rotation SRWC plantations to increase productivity and reduce the time to develop a commercially harvestable crop, while enhancing soil productivity potential of formerly cultivated fields.

Figure 1: Location of Trice Experimental Forest, Sumter County, SC

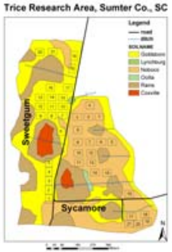

Figure 2: Location of plots within species and soil type. Sweetgum plots were located in the Goldsboro soils, Sycamore were located in Noboco soils.

Materials and Methods

Figure 3: ATV used to collect pore water samples from porous cup lysimeters. A peristaltic pump (A) and length of clear vinyl tubing (B) was used to collect the samples. A bicycle type pump (C) was used to apply the vacuum.

Figure 4: Soil Sampling sweetgum plots at depths of 0-5, 5-15, 15-30, 30-60, and 60-90 cm. Composite samples from 4-6 borings per plot were taken, half within row and half between row.

Site Description

The study site is located on the William H. Trice Forest in Sumter County, South Carolina (Figure 1). The Trice Forest is within the Middle Coastal Plain, and the surrounding area is typical of this region and includes urban/residential, agriculture, tree plantations, and natural mixed pine/hardwood forest stands. The plots were located in the sycamore (*Platanus occidentalis)* and sweetgum (*Liquidambar styraciflua*) plantation. The stands for each species were 9 years old (planted in 1997) at initiation of the study. The plots were located in the dominant soil series for each species, Goldsboro for sweetgum and Noboco for sycamore (Figure 2).

Experimental Design

Established sweetgum and sycamore stands were tested for late-rotation N response. Treatments were applied at an annual rate of 0, 30, 50 and 80 kg N ha^{-1}; and a biennial application of 60, 100, 160 kg N ha^{-1} (applied as NH_4NO_3) to 0.2 ha plots and were arranged in a randomized complete block design with three replications. Plots were randomly assigned to each species by soil series and blocked by DBH. Pore water was collected by porous cup lysimeter (Figure 3) at two depths (Ap - E boundary, Bt with matrix chroma ≤2), and soil samples were taken at 0-5, 5-15, 15-30, 30-60, and 60-90 cm depths (Figure 4). Both were analyzed for NH_4-N and NO_3-N. Leaf samples and litter samples were collected and analyzed for total N. Intercepted photosynthetically active radiation transects were measured to estimate leaf area index and leaf biomass.

Results and Discussion

Drought during the course of this study and highly variable water table resulted in inconsistent data from the lysimeters. Due to the missing data points and high variability of the data, statistical analysis could not be performed. Preliminary analyses indicated that the rates were too similar for differences to be detected; hence, only the control, 80 kg, and 160 kg (biennial application) data are presented.

During the course of the study, the sycamore showed ever worsening signs of Sycamore Decline. This resulted in in a stand loss in excess of 30% by the end of the first year as well as a thick undergrowth. Therefore, the sycamore treatments were dropped from the study and a decision was made to focus on sweetgum.

As expected, leaching loss was affected by the treatment application. Soil NO_3-N and NH_4-N concentrations as determined by KCl extraction showed some signs of nitrate movement through the profile; however, this did not represent a significant loss of nitrate, as the concentrations measured did not exceed 3.5 mg kg^{-1}. The second application of the 80 kg annual treatment was clearly detected 30 days after application when soil samples were collected in April, 2007. Both soil NO_3-N and NH_4-N concentrations increased significantly in the profile (Figure 5).

Figure 5: Soil NH4-N and NO3-N with depth grouped by treatment for each sampling date. Samples for 4/2007 were taken 30 days after application of the annual application of the 80 kg treatment.

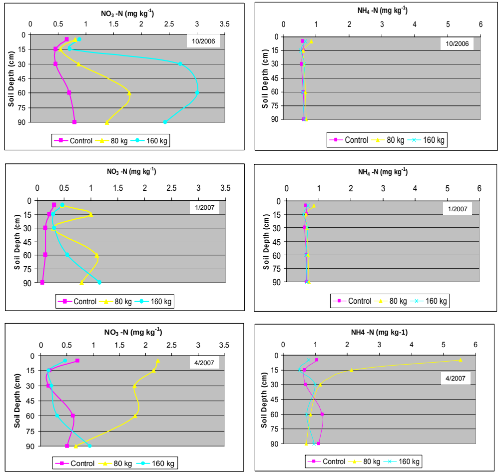

Table 1: Summary of One way ANOVA testing for block and treatment effects. With only first year response data, there is insufficient data to run multiple regression testing treatment effects and interactions. NS=Not significant at p ≤ 0.05.

	Leaf Biomass	N accumulation (leaf)	Litter N	Ht	DBH
Block	NS	NS	NS	NS	NS
Treatment	NS	NS	R^2=0.698 p=0.0277	NS	NS

Growth response and litter data were collected to measure treatment effect. Growth response measurements included tree height, DBH, leaf biomass, and leaf N accumulation. Each of these response data were tested for block and treatment effect by analysis of variance. There was no block effect detected in the growth response and litter data. There was no statistically significant treatment effects detected with the exception of a significant treatment effect on litter total N. This indicates that much of the applied fertilizer may be bound in the litter still, and may explain the lack of significant growth response from the fertilizer applications.

Conclusions

Soil samples showed no significant leaching losses as NO_3-N nitrate concentrations did not exceed 3 mg kg^{-1}, approximately 6 kg ha^{-1}. The total amount of N in the sampled profile as NO_3 and NH_4 did not exceed 14.3 kg ha^{-1}.

The applied N fertilizer treatments, at present, do not show a significant growth response. This may be due the fertilizer N being taken up and cycling in the organic fraction or the growth rates of sweetgum. Also, the treatments were applied 9-10 years after establishment of the plantation. This is well after the average canopy closure of plantation hardwoods (4-6 years). Further, mature hardwood trees have significant N stores in roots from which they draw. The second year data may show an increased growth response in the sweetgum to the treatments; however, it does not appear that mid- to late-rotation N fertilization improves harvestable yields in plantation sweetgum.

Future Research

Research continues on this site to better understand N cycling in an attempt to develop a comprehensive N budget for this type of forest system. These studies include plot and laboratory scale mineralization studies using labeled (^{15}N) fertilizers to trace N movement in litter, soil, and tree.

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