BIOMASS, NITROGEN, AND PHOSPHORUS ACCUMULATION IN 4-YEAR-OLD INTENSIVELY MANAGED LOBLOLLY PINE AND SWEETGUM PLANTATIONS

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Abstract—Knowing the nutrient uptake potential of plantations of fast-growing species is essential to designing land-based tertiary water treatment facilities. This study was conducted to estimate the biomass of 4-year-old, intensively managed loblolly pine (*Pinus taeda)* and sweetgum (*Liquidambar styraciflua)* plantations and to estimate the N and P contained in that biomass. The cumulative effects of competition control only and competition control, irrigation, fertilization and pest control were investigated on an abandoned peanut field in Decatur County Georgia on a Lakeland sand soil. Planted at 1,157 trees/ha, loblolly pine accumulated 57.3 mg/ha dry biomass 4 years after planting and sweetgum accumulated 26.5 mg/ha dry biomass in the maximum treatment plots. Sweetgum was more responsive to the maximum treatment with a biomass increase of 388 percent compared to a 217 percent increase in loblolly pine biomass. In the maximum treatment plots, loblolly pine accumulated 330 kg N/ha and 35 kg P/ha compared to sweetgum accumulation of 137 kg N/ha and 15 kg P/ha.

INTRODUCTION

In 1994 International Paper Company installed their Forest Growth Maximization Study to determine the potential of highly intensive tree culture on abandoned agricultural land. The most likely motivation for such a study would be to determine the economic feasibility of cultural treatments that are known to increase tree growth. From previous research we know that competition control, soil moisture management, nutrient amendment all increase the growth rate. Pest control also contributes to an increased individual tree growth rate by maintaining the terminal shoots and minimizing defoliation. If the growth response is large enough, these treatments can be made operational over large areas at a cost.

We recognized another opportunity in this study; using plantations of pine or fast-growing hardwoods for tertiary sewage treatments. Land application of secondary treated sewage is not new, but it does require knowledge of how rapidly the applied nutrients can be assimilated into biomass. If the application rate exceeds the assimilation rate, then excess nutrients will not be fixed in biomass and could leave the system by leaching. Our interest in this study was to estimate the N and P fixed into tree biomass that will provide an estimate of the nutrient loading possible without exceeding uptake. Although the design of the experiment is not a land application study, we recognized the potential to derive loading rates. The objective of this research was to estimate the aboveground biomass, N, and P pools of both loblolly pine (*Pinus taeda)* and sweetgum (*Liquidambar styraciflua)* in the control and maximum treatments.

MATERIALS AND METHODS

The field installation was on abandoned agricultural peanut (*Arachis hypogaea)* field in Decatur County Georgia, approximately 16 km southwest of Bainbridge Georgia. The soil was a Lakeland sand (a Typic Quartzipsamment) on International Paper Company's Silver Lake Farm. This installation was a randomized complete block design with three replications of four cumulative treatments. A fourth replication, designated for destructive sampling, contained only the control and maximum treatments. The control treatment consisted of ripping to a 60-cm depth and constant competition control. The irrigation treatment was the control treatment with trickle irrigation of 24 l/day/tree of water pumped from the near-by Silver Lake. The fertigation treatment was the irrigation treatment with the addition of 135 kg N/ha/yr, 33 Kg P/ha/yr and 130 kg K/ha/yr. The maximum treatment was the fertigation treatment with insect pest control, primarily, tip moth (*Rhyacionia frustrana*) for loblolly pine. Each of the complete replications had eight plots; all four treatments with both loblolly pine and sweetgum.

The trees were planted in March 1995 on a 2.4 m X 3.6 m spacing in plots with 12 rows of 18 trees per row.
In December 1998 we systematically selected 40 measurement trees in the center of each plot in replications 1,2, and 3 and 80 trees in replication 4. Diameter outside bark at groundline, breast height, and at the base of live crown was measured with a diameter tape or with calipers. The base of live crown was defined as the base of the lowest live branch on the tree. Distance from the ground to the

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base of live crown and to the top of the terminal bud was measured with a fiberglass tape attached to a telescoping pole. An observer with an unobstructed view of the terminal bud at approximately a 45 degree angle, determined when the pole tip was level with the top of the terminal bud.
In March 1999 ten randomly selected loblolly pine trees in both the control and maximum plots of Replication 4 were destructively sampled. Diameter at groundline and breast height were measured, the tree was felled by cutting at groundline and the distances to the base of live crown and the top of the terminal bud were measured. Branches were then removed from the bole and both components immediately weighed. Bole and branch sub-samples were taken and weighed. This same procedure was repeated in April 1999 with sweetgum trees in the control and maximum plots of replication 4.

In the laboratory, bole and branch samples were dried at 65 degrees Celsius in a forced-air oven to a constant weight. The bole samples were reweighed and the branch samples were separated into foliage and branches and these components reweighed. Tissue samples were prepared and analyzed for total Kjeldahl N and P by the procedure described in Williams and Gresham (2000). Biomass and nutrient pool sizes were estimated by calculating the average diameter at breast height (dbh) and total tree height by treatment and block. Simple linear regression equations were calculated to predict tree dry foliage weight, branch weight, crown weight, bole weight and total tree weight from dbh squared times total height. Nitrogen and P concentrations of the foliage, branch and bole samples were averaged by treatment for each species and these averages were combined with the biomass estimates to estimate N and P pool sizes on an area basis.

RESULTS

Foliage N and P concentrations were most affected by species and treatment (Table 1). Sweetgum foliage N and P were much higher than for loblolly pine and sweetgum foliage concentrations were much more affected by the maximum treatment compared to loblolly pine. For the branch component, there was little difference in concentrations between sweetgum and loblolly pine in the control treatment and only loblolly pine N showed much maximum treatment response. There was little response to treatment in both sweetgum and loblolly pine bole N and P, and loblolly pine did have more N that did sweetgum.

Loblolly pine was larger and accumulated more N and P compared to sweetgum, but sweetgum was more responsive to the treatments (Table 2). Loblolly pine averaged 13 cm dbh 4 years after planting with the maximum treatment. The 10 cm dbh of trees in the control plots probably reflected an old field effect of residual fertilizer. The total height of loblolly pine in the maximum plots was 7 m compared to 6.1 m for sweetgum. Although much smaller, sweetgum showed an almost 300 percent dbh response to treatment. Sweetgum in the control plots averaged 3 cm dbh and 3 m tall after 4 years with competition control, but without irrigation and fertilization. The height response of sweetgum to treatment was less than the diameter response (206 percent versus 298 percent) but still greater than loblolly pine's response (139 percent). The crown, bole and total aboveground biomass pools (Table 2) reflect the same trends seen in the height and diameter data. After 4 years in the field, loblolly pine produced over 57 mg/ha oven dry, above ground, biomass with the maximum treatment, but only 46 percent was in the bole. Sweetgum in the maximum treatment produced less biomass (27 mg/ha) more bole biomass (60 percent) and was much more responsive to treatment. The bole biomass increased 535 percent and total biomass increased 388 percent comparing the control to maximum treatments.

The distribution of N between species and treatments reflected the biomass differences. Loblolly pine accumulated 330 kg N/ha after 4 years in the field with the maximum treatment compared to 137 kg N/ha for sweetgum. As was the case with biomass, sweetgum N accumulation was more responsive to treatment; crown N increased by 322 percent, bole N increased by 519 percent and total sweetgum N increased by 350 percent. Phosphorus

Table 1—Average (and one standard error) Kjeldahl N and P concentrations (percent) in foliage, branches and boles of 5-year-old loblolly pine and sweetgum trees in plots receiving competition control only (Control) and competition control, irrigation, fertilization, and pest control (Maximum)

Component	Treatment	Species	percent N	percent P
Foliage	Control	Loblolly pine	1.33 (0.03)	0.13 (0.00)
		Sweetgum	2.21 (0.08)	0.26 (0.02)
	Maximum	Loblolly pine	1.40 (0.02)	0.14 (0.00)
		Sweetgum	3.07 (0.08)	0.40 (0.04)
Branch	Control	Loblolly pine	0.44 (0.04)	0.06 (0.01)
		Sweetgum	0.47 (0.03)	0.06 (0.01)
	Maximum	Loblolly pine	0.53 (0.02)	0.06 (0.00)
		Sweetgum	0.44 (0.02)	0.04 (0.00)
Bole	Control	Loblolly pine	0.25 (0.01)	0.03 (0.00)
		Sweetgum	0.19 (0.01)	0.02 (0.00)
	Maximum	Loblolly pine	0.26 (0.01)	0.03 (0.00)
		Sweetgum	0.19 (0.01)	0.02 (0.00)

Table 2—Average (and one standard error) dbh, height, biomass, and N and P accumulation of 5-year-old loblolly pine and sweetgum trees in plots receiving competition control only (Control) and competition control, irrigation, fertilization, and pest control (Maximum)

	Loblolly pine				Sweetgum			
	Control		Maximum		Control		Maximum	
DBH (cm)	9.7	(.1)	13.7	(.1)	3.1	(.3)	9.4	(.3)
Total height (m)	5	(.2)	7	(.1)	3	(.1)	6.1	(.1)
Crown Biomass (kg/ha)	15,216	(470.0)	31,312	(326.0)	3,816	(889.0)	10,552	(803.0)
Bole Biomass (kg/ha)	11,192	(504.0)	26,020	(284.0)	2,983	(598.0)	15,981	(1,153.0)
Total Biomass (kg/ha)	26,410	(974.0)	57,332	(609.0)	6,829	(1,486.0)	26,533	(1,956.0)
Crown N (kg/ha)	143	(4.0)	261	(2.0)	33	(7.0)	107	(13.0)
Bole N (kg/ha)	28	(1.0)	69	(1.0)	6	(1.0)	30	(2.0)
Total N (kg/ha)	171	(6.0)	330	(2.0)	39	(9.0)	37	(15.0)
Crown P (kg/ha)	15	(0.5)	27	(0.2)	4	(1.0)	13	(1.5)
Bole P (kg/ha)	3	(0.1)	8	(0.1)	1	(0.1)	3	(0.2)
Total P (kg/ha)	18	(0.6)	35	(0.3)	5	(1.0)	15	(1.7)

accumulation results are similar to the N results. Loblolly pine accumulated 35 kg P/ha compared to sweetgum's 15 kg P/ha for the maximum treatment.

DISCUSSION

Loblolly pine height growth in the control plots indicates that the estimated site index (25-year base age) would be 60 (Pienaar and Shiver 1980) to 70 (Trousdell and others 1974). Site index for the maximum treatment plots is estimated to be 87 (Pienaar and Shiver 1980).
Sweetgum productivity in the maximum plots exceeded the sycamore (*Platanus occidentalis)* productivity on fertilized plots reported by Steinbeck and Brown (1976). They reported a green weight biomass of 105 Mg/ha after 4 years at a 1.2 by 1.2 m spacing. Assuming a 50 percent dry weight, this is 52 mg/ha at 5.8 times the planting density of our sweetgum that produced 26 mg/ha after 4 years in the field.

One of the reasons for doing this research was to determine the feasibility of slow-rate land application of wastewater on plantations of fast-growing species. Although leaching data are needed to provide a more complete picture, these data provide a useful framework. In the loblolly pine plots receiving the maximum treatment, N was applied at 135 kg/ha/yr and after 4 years 330 kg N/ha was accumulated. The N accumulated in tree biomass is 61 percent of the N applied during that 4-year period. A typical N loading rate for land application would be 3 to 5 kg N/ha/d (Kadlec and Knight 1996) which equates to pumping for 27 to 45 days a year to achieve the 135 kg/ha/yr applied in this experiment. This rough comparison indicates that from 8 to 13 ha will be needed for every ha to receive wastewater if pumping were year around. Another major consideration is whether the site could handle the high hydraulic loading of 208 l/tree/d (Kadlec and Knight 1996) compared to the loading of this study (24 l/tree/d).

CONCLUSIONS

These data present biomass, N and P accumulation rates for fast-growing species and provide several implications for intensive management of loblolly pine and sweetgum. The growth rate of loblolly pine with competition control only indicates that an old-field effect was present. If irrigation and fertilization treatments are added, loblolly pine will grow to 7 m tall and 13 cm dbh after 4 years in the field. At the planting spacing of 1,157 trees/ha loblolly pine can accumulate 57 mg/ha dry biomass. However, sweetgum biomass and nutrient accumulation was much more responsive to the treatment than was loblolly pine. The increase in sweetgum biomass and nutrient accumulation ranged from 267 to 535 percent compared to 181 to 261 percent for loblolly pine. Sweetgum leaves from the maximum treatment had a high N (3 percent) and P (0.4 percent) concentrations and could be used as an organic fertilizer. Finally the treatments did not affect the bole N or P content, but in most cases for branch biomass, N and P was higher in trees from the control plots. We speculate that although the branches and boles did accumulate more nutrients in the maximum plots, the concentration was decreased by the great increase of biomass.

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