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Effect of Fertilization on Thinned Loblolly Pine Growth in an Old-field Site in Washington County, Georgia

E. David Dickens, Ph.D. - Associate Professor of Forest Productivity,
David J. Moorhead, Ph.D. – Professor of Silviculture,
Bryan McElvany – Treutlen County Extension Coordinator, and
Sidney Law – Washington County Extension Coordinator
The University of Georgia Warnell School of Forestry and Natural Resources (WSF&NR) and College of Agriculture and Environmental Sciences (CAES)
Email: ddickens@uga.edu

Abstract

Many private non-industrial forest landowners (NIPFLs) in Georgia and the southeastern U.S. are interested in fertilizing their pine plantations. These landowners wonder if the benefits of fertilization with reduced pine stumpage prices and rising fertilizer prices since 1998 are worth the investment. Forest industry has fertilized an average of 1 million pine plantation acres per year between 1995 and 2005 on sites that have been in trees for at least one rotation. There is also an opportunity to fertilize approximately 2/3 of a million acres of cropland and pastureland planted in Georgia in the mid-1980's to early 1990's. There is very little literature available pertaining to the growth response of loblolly and slash pine to fertilization on these old-field sites. UGA WSF&NR and CAES faculty installed three fertilizer trials on old-field sites in the Coastal Plain of Georgia in 2000-2001 to determine the benefits of adding nutrients including nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), sulfur (S), boron (B), and copper (Cu) to these relatively fertile sites. Financial support of this project comes from the Potash & Phosphate Institute – Foundation for Agronomic Research (PPI-FAR). This paper details 4-year fertilization results in a 15-year-old thinned loblolly pine plantation planted on a former corn field in Washington County, Georgia.

Four-year results (age 15- through 19-years) indicate that there were negligible (statistically non-significant) benefits to the one-time N+P, N+P+K, or N+P+K+Mg+S +B+Cu fertilizer application. The complete fertilizer treatment increased mean diameter growth increment by 0.18 inches (a 10% gain), height by 0.5 feet/tree, (a 3.5% gain), and volume/tree by 0.65 ft^3 (an 8% gain) when compared to no fertilization. There was a small NPK fertilization volume per acre gain of 6% over the unfertilized loblolly pine after the 4-year study period. Forest landowners should continue to use well established fertilization diagnostic tools of leaf area (LAI) estimates, soil sampling for available P,

foliar sampling, and soil series knowledge for cost-effective fertilization prescriptions. Fertilization, in this case, was not cost-effective over the 4-year period.

Introduction

Between 1986 and 1992 over 645,000 acres of marginal cropland in Georgia were planted to predominantly loblolly and slash pine stands under the Conservation Reserve Program (CRP). Thousands of acres of marginal cropland were also planted to primarily loblolly pine in Alabama, Louisiana, Mississippi, North Carolina, and South Carolina during the same time period. The growth rate of these stands initially was very dramatic, in some cases approaching 3 to 4 cords acre^{-1} year^{-1}, for the first 10 to12 years. The accelerated growth rate on these old-fields can be attributed primarily to three factors: minimal competing vegetation (essentially no woody competition for the first 8 to10 years), a residual fertilizer effect, and good surface soil tilth for root development. Estimated macro- and micro-nutrient uptake rates for loblolly and slash pine stands on these old-fields may be on the order of 2 to 4 times that of cut-over sites to achieve such early dramatic growth rates. Micro-nutrients such as copper and boron, present in small amounts at time of planting, may be at critical levels as these stands develop. Foliar macro-nutrient (N, P, K, and Mg) levels in some loblolly and slash pine stands are at or below sufficiency in some of these old-field stands.

Private non-industrial forest landowners are very interested in fertilization of their pine plantations. They own 2/3^{rds} of the forest land in GA and SC. Many own tractors and spreaders and are willing to apply fertilizers themselves. Very little information exists on the magnitude and duration of response to N+P, N+P+K, or N+P+K+Mg+S+Cu+B fertilization on old-field and pasture land sites that have been planted in loblolly or slash pine. Pine pulpwood versus chip-and-saw and small sawtimber price disparities from 2005 through 2010 (pulpwood is the same as to 1/5th of chip-and-saw per cord and 1/3 to 1/6th of sawtimber per cord) have many NIPF landowners wanting to shift wood to the more valuable product classes as well as grow more wood. Conservative estimates of annual pine straw income of \$50 and \$150 acre^{-1} for loblolly and slash pine, respectively, on many old-field sites may also be enhanced with fertilization. Pine straw revenues for forest landowners have increased dramatically in Georgia from \$15.5 million in 2000 to \$23.5 million in 2002 and \$80 million in 2008 and 2009.

Each old-field pine stand has its own set of site characteristics, some possibly reaching a macro- or micro-nutrient deficiency(ies) much sooner than others. Generally, these stands have been thought to have sufficient nutrients to last for a portion to all of a rotation. This may not necessarily be the case for some of these plantations.

The project duration is 5 years (1 February 2001 through 31 January 2006). Three of these old-field planted sites have been located in Georgia: a thinned 12-year-old slash pine stand in Dodge County, an unthinned 8-year-old slash pine stand in Montgomery County, and a 15-year-old thinned loblolly pine plantation in Washington County. This paper summarizes the old-field, thinned loblolly pine plantation in Washington County, Georgia.

Objectives

This fertilizer trial using macro- and macro+micro-nutrients installed in three old-field slash and loblolly stands in a randomized complete block design with 3 or 4 replications/treatment addresses the following major objectives: (1) quantify diameter, height, live crown ratio, wood volume/tree, and wood volume/acre growth from the fertilizer treatments compared to unfertilized pine tree and stand growth, (2) if there is a significant growth response to fertilization then discern the magnitude and duration of wood volume response to the fertilizer combinations, (2) determine any changes in product class distributions (% pulpwood, superpulp, chip-n-saw, and sawtimber) and (3) estimate the economic benefit of fertilization where there may be a significant pine straw and/or wood volume response, and (4) discern if/when fertilizers are to re-applied to maintain increased volume gain.

Methods

The soil series on all sites were delineated by a NRCS soil mapper. Gross treated plots and internal permanent measurement plots were installed in the delineated soil series area. Forty feet of untreated buffer was between each gross treated plot. Replications (blocks) were laid out on the contour to minimize soil moisture differences. Baseline soil (10/plot @ 0-6”) samples were taken in each plot prior to treatment at all three sites. Plot leaf area indexes (LAI) were estimated using the NC State University Forest Nutrition Cooperative (NCSUFNC) protocol in midsummer during the study period. Three digital photos per plot of multiple tree crowns were also taken each summer from fixed points to estimate crown and leaf area changes. Foliage samples (3 dominant trees/plot, upper 1/3 crown, south side, first flush of previous year’s growth) were taken during the dormant season. Soil and foliage analysis includes N (foliage only), P, K, Ca, Mg, S, Cu, Mn, Zn, and B. Soil pH for each plot was also determined. All living crop trees in each plot have been aluminum tree tagged, numbered and measured for dbh and total height prior to treatment. Live crown ratio of all trees in each plot were also measured prior to treatment. The Washington county site had 16 plots installed (4 reps of 4 treatments).

Treatments

Randomly assigned to each plot was an N+P, N+P+K, or N+P+K+Mg+S+Cu+B fertilizer treatment. Untreated control plots served as reference plots. The one-time fertilizer application levels were 200 lbs N acre^{-1} + 40 lbs elemental-P + 75 lbs elemental-K + 30 lbs Mg + 60 lbs S + 4.5 lbs Cu + 3 lbs B acre^{-1}. Fertilization application timing was targeted for late winter to early spring (February-April, Table 1) to minimize N losses and maximize N use. Urea was used as the dominant N source at the Dodge County site while ammonium nitrate was used as the dominant N source at the Toombs and Washington County sites.

Project Background

The dominant soil series present at the Washington County site was Orangeburg (fine-loamy with an argillic @ 8-15”, Typic Paleudults). Soil available-P was compared to the sufficiency threshold of 10 lbs acre^{-1}. Foliar macro- and micro-nutrient status prior to fertilizer application and after fertilizer application was compared to established loblolly pine foliar nutrient sufficiency guidelines (Table 2). Baseline soil pH and available P, K, Ca, Mg, Zn and Mn by treatment are found in Table 3. Baseline loblolly pine foliar N, P, K, Ca, Mg, S, Mn, B, Cu, and Zn are found in Table 4. All living crop trees in each plot were aluminum tree tagged, numbered and measured for dbh, total height, height to base of live crown, and height to a defect (fork, stem canker, excessive branching or sweep) prior to treatment (February 2001). Live crown ratios of all trees/plot were determined during the study period. Mean dbh, basal area, height, live crown ratio, volume/tree and volume/acre prior to fertilizer application (N, P in February, K, Mg, and S in April 2001), 2- and 4- years post-application and incremental growth were quantified.

Each tree in each plot was merchandised based on form, length to base of fork, dbh and total height. Forty to sixty percent of the Washington county thinned stand's plot trees are currently in the chip and saw class (dbh > 8.5 inches with good stem form).

A foliar active herbicide (3quarts of 41% Glyphosate + 1% surfactant @ 18 GPA using an ATV and boom sprayer) was applied to plots 1-8 of the Washington County site in September 2001. The herbicide was estimated to be 75% to 85% effective on average. There were no significant growth parameter benefits to the one-time herbicide application compared to the non-herbicide plot (# 9-16) treatment counterparts.

Table 1. Application timing of fertilization and type/amounts of fertilizer materials used.

	App. date	**Nitrogen**	**N+P**	**Potassium**	**K+Mg+S**
		-------------------------------lbs/ac-----------------------------------			
	2/28/01(N+P) 4/9/01(K,Mg,S)	500 NH_4NO_3	125 DAP	150 muriate of potash	50 muriate of potash + 240 K-mag
Micro-nutrients				**Boron (B)**	**Copper (Cu)**
	7/2/02 (10%B, 15%Cu) @ 30 lbs/ac			B as Sodium Calcium Borate(3#/ac)	Cu as Cu-sulfate and Cu-oxide (4.5#/ac)
				B as Sodium Calcium Borate(3#/ac)	Cu as Cu-sulfate and Cu-oxide (4.5#/ac)

Table 2. Foliar nutrient sufficiency (minimum) guidelines for loblolly, longleaf, and slash pine

Nutrient	Loblolly pine[a]	Longleaf pine[b]	Slash pine[a]
	-- percent --		
Nitrogen (N)	1.2	0.95	1.0
Phosphorus (P)	0.12	0.08	0.09
Potassium (K)	0.30	0.30	0.25 – 0.30
Calcium (Ca)	0.15	0.10	0.08 – 0.12
Magnesium (Mg)	0.08	0.06	0.06
Sulfur (S)	0.10	--	0.08
	---------------------------------- parts per million (ppm) ----------------------------------		
Boron (B)	12	--	4 – 8
Copper (Cu)	2 – 3	--	1.5 – 3
Manganese (Mn)	20 – 40	--	20 – 40
Zinc (Zn)	10 – 20	--	10 – 20

[a] Allen (1987); Jokela (2004); Pritchett and Comerford (1983); Wells, Crutchfield, Berenyi, and Davey (1973).
[b] Blevins, Allen, Colbert, and Gardner (1996) for N, P, K, Ca, and Mg.

Table 3. Pre-application (2/10/01) mean soil pH, available macro-, and micro-nutrient levels (range) by fertilizer treatment in the old-field thinned 15-year-old loblolly stand at the Washington county, Georgia site (Orangeburg soil).

--lbs/acre--

Treatment	pH	P	K	Ca	Mg	Zn	Mn
Control (no fertilizer)	5.3 (5.1-5.6)	22 (18-28)	40 (36-48)	301 (250-431)	43 (29-56)	24 (14-35)	17 (13-22)
NP	5.4 (5.2-5.6)	21 (17-27)	42 (39-49)	314 (261-370)	45 (36-66)	29 (21-39)	16 (15-17)
NPK	5.4 (5.2-5.5)	12 (8-18)	46 (42-56)	296 (288-307)	57 (46-74)	25 (9-49)	17 (14-19)
NPKMgSBCu	5.5 (5.3-5.6)	18 (10-24)	48 (33-67)	394 (217-461)	65 (28-79)	35 (33-40)	18 (15-22)

Table 4. Pre-application (2/10/01) mean (range) foliar macro- and micro-nutrient concentrations in the old-field thinned 15-year-old loblolly pine stand at the Washington county, Georgia site (Orangeburg soil).

---------------------------------percent------------------------------------ ------------------ppm------------------

Treatment	N	P	K	Ca	Mg	S	Mn	B	Cu	Zn
Control	1.33 (1.15-1.53)	*0.10* [†] *(.09-.11)*	0.*30* (.*28*-.32)	0.16 (.11-.23)	0.09 (.08-.11)	0.12 (.11-.13)	191 (103-242)	*12* (10-14)	*2* (1-3)	25 (18-36)
NP	1.31 (1.18-1.46)	*0.10* (.09-.12)	0.32 (.*26*-.37)	0.16 (.12-.20)	0.08 (.07-.09)	0.13 (.12-.13)	200 (150-235)	*11* (8-17)	*3* (2-4)	25 (15-33)
NPK	1.28 (1.18-1.42)	*0.12* (.10-.14)	0.34 (.31-.39)	0.18 (.15-.21)	0.10 (.08-.12)	0.13 (.11-.17)	216 (174-261)	*10* (10-11)	*2* (2-3)	26 (15-39)
NPKMgSBCu	1.33 (1.17-1.62)	*0.11* (.10-.12)	0.35 (.33-.36)	0.17 (.15-.19)	0.10 (.08-.12)	0.13 (.11-.15)	197 (168-230)	*9* (6-13)	*2* (2-3)	23 (16-32)

[†] Foliar nutrients in *italics* are at or below sufficiency for loblolly pine (Wells and Crutchfield 1973, Allen 1987, Jokela 2004).

RESULTS over the 4-year study period

Pre- and post-fertilizer application soil and foliage levels by treatment

Soil available-P was above the 10 lbs/acre sufficiency level in the control, NP, NPK, and NPKMgSBCu plots prior to fertilizer treatments (Table 3). Soil available P was above sufficiency for the control and all fertilizer treatment plot means 1-, 2-, and 3-years after the fertilizer was applied (Table 5). There were no statistical differences in soil available P in 2002, 2003, or 2004 (2005 soil was not collected in February 2005 due to very wet conditions).

Mean foliar N was above sufficiency (Table2) for all treatments (Table 4) prior to fertilizer application. Mean foliar P, B, and Cu concentrations were at or below sufficiency (Table 2) for all treatments (Table 5) prior to fertilizer application. Foliar N was above sufficiency for the control and all fertilizer plot means throughout the study period. Foliar P was at or below sufficiency for the control and all fertilizer treatment plots 1- and 2-years after application (Table 6). There were statistical differences in foliar P in 2003 (2-years after treatment) with the control level being less than the NP and NPK level. Foliar P was above sufficiency 3- and 4-years after the fertilizer was applied for the control and all fertilizer treatments (Table 5). Foliar K was above sufficiency for the control and all fertilizer treatments throughout the study period. By the end of the 4-year study period only the complete fertilizer Ca and all fertilizer treatments Cu foliar levels were at or below sufficiency. Foliar N, P, K, Mg, S, and B levels were above sufficiency for the control and fertilizer treatments at the end of the study period.

Leaf area index estimates

Leaf area index (LAI) estimates are highly correlated to the growth rate of a southern pine stand. Ocular leaf area estimates can be very subjective. Our ocular leaf area estimated ranged from 1.5 to 3.0 across the 16 thinned loblolly pine study area plots prior to fertilizer application with an average of 2.25 LAI. Two-year post-application (August 2003) LAI estimate means were: 3.24 for the control (range of 2.77 – 3.87), 3.28 for the NP treatment (range of 3.13 – 3.40), 3.18 for the NPK treatment (range of 3.00 - 3.33), and 3.35 for the complete fertilizer treatment (range of 3.07 – 3.53).

Live crown ratios

Loblolly pine live crown ratios ranged from 37 to 40% after the thinning and prior to fertilization across the 16 plots. Live crown ratio means were 41, 42, 40, and 42 % for the control, NP, NPK, and NPKMgSBCu (complete fertilizer treatment), respectively in February 2003 two-years after treatment. Live crown ratios increased by 3.3, 2.9, 1.2, 0.7 percentage points for the control, NP, NPK, and complete fertilizer treatments, respectively between February 2003 and February 2005. There were no live crown ratio statistical differences between fertilizer treatments 2- and 4-years after application.

Pre- and post-fertilizer application loblolly pine growth by treatment

Mean dbh (diameter at 4.5 feet above groundline), total height, live crown ratio, volume/tree, and volume/acre were tested for statistical significant differences (using Duncan's Multiple Range Procedure @ the 5% alpha level) during the 4-year study period. There were no statistical mean differences among the treatments for dbh (diameter at 4.5 feet above groundline), total height, live crown ratio, volume/tree, and volume/acre prior to initial fertilizer treatments (February 2001, Table 6). The same growth parameters continued to be non-significant between treatments 2- and 4-years after the fertilizers were applied (Table 6).

Mean dbh, total height, volume/tree, and volume/acre 2- and 4-year growth increments between treatments were also not significantly different. There were only minor gains of 10% (0.18 inches/tree) for diameter growth, 3.5% (0.5 feet/tree) for height growth, and 8% (0.65 ft^3) for volume/tree with the NP (diameter) or complete fertilizer treatment (height and volume/tree) compared to the control over the 4-year study period (Table 7). The NPK treatment increased volume per acre over the unfertilized loblolly pine by a small amount (6% or 84 ft^3/acre). The three fertilizer treatments mean total volume per acre growth increment was1381 ft^3/acre (3.92 cords/ac/yr or 10.6 tons/ac/yr, Table 6). The control plots mean volume per acre growth increment was 1333 ft^3/acre (3.79 cords/ac/yr or 10.2 tons/ac/yr, Table 6).

Pine mortality was overall low between February 2001 and 2005 (2% across the four fertilizer levels). Mortality was 2.3% for the control, 1.1% for the NP treatment, 0% for the NPK, and 4.8% for the complete fertilizer treatment (Table 7). Pine mortality exhibited no discernable trend by fertilizer treatment and diameter class (Figure 1).

Product class distributions

Since the loblolly pine stand was thinned removing mostly trees with defects and small diameter stems with slow growth rates, there were no pulpwood sized trees (4.6 to 6.6 inch dbh) prior to the fertilizer treatments in the spring of 2001. Superpulp (SP, 6.6 to 8.6 inch dbh) sized trees volume per acre ranged from 276 ft^3/acre (complete fertilizer plots mean) to 444 ft^3/acre (NPK plots mean, Table 6) prior to fertilizer treatment. Chip-n-saw (CNS, ≥ 8.6 inch dbh) sized trees volume per acre ranged from 1239 ft^3/acre (NPK plots mean) to 1464 ft^3/acre (complete plots mean, Table 6) prior to fertilizer treatment. The control treatment produced statistically similar amounts of SP and CNS over the 4-year study period (-260 and 1004 ft^3/acre, respectively) as the three fertilizer treatments (-310 and 999 ft^3/acre, respectively, Table 7).

Table 5. Foliar nutrient and soil available P levels one (2002), two (2003) three (2004), and four (2005) years post fertilization in a thinned old-field loblolly pine plantation in Washington County, Georgia (Orangeburg soil).

		Foliage								
Fertilizer treatment	Year	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	B (ppm)	Cu (ppm)	Soil P (lb/ac)
	2002									
Control		1.35# b	*0.08* †	0.34	*0.15 b*	0.13 ab	0.16 bc	21	*2*	16
200N+25P		1.48 ab	*0.10*	0.34	0.17 ab	0.12 b	0.15 c	19	*2*	20
200N+25P+75K		1.65 a	*0.12*	0.33	0.18 a	0.16 a	0.18 ab	24	*3*	15
NPKMgSBCu		1.63 a	*0.12*	0.34	0.19 a	0.17 a	0.20 a	19	*2*	16
	2003									
Control		1.40 c	*0.108 c*	0.36 b	*0.15 a*	0.09	0.13	*11 b*	*2*	18
200N+25P		1.61 b	*0.115ab*	0.36 b	*0.12 b*	*0.07*	0.15	15 b	*2*	24
200N+25P+75K		1.70 ab	*0.120a*	0.41 a	*0.14 ab*	*0.08*	0.16	*10 b*	*2*	18
NPKMgSBCu		1.79 a	*0.113bc*	0.40 a	*0.12 b*	*0.07*	0.15	34 a	*2*	26
	2004									
Control		1.50 ab	0.14	0.42 ab	0.20	0.11 a	0.14 ab	13	*3*	16
200N+25P		1.37 b	0.12	0.37 b	*0.15*	*0.08 b*	0.13 b	*11*	*3*	23
200N+25P+75K		1.68 a	0.14	0.44 a	0.16	*0.08 b*	0.16 a	*12*	*3*	20
NPKMgSBCu		1.66 a	0.13	0.48 a	0.16	0.09 b	0.14 ab	22	*3*	21
	2005									
Control		1.37	0.14	0.43 b	0.19 a	0.11 a	0.12	17	*2*	
200N+25P		1.40	0.13	0.41 b	0.16 ab	0.09 b	0.13	14	*2*	
200N+25P+75K		1.40	0.13	0.49 a	0.17 ab	0.12 a	0.13	19	*2*	
NPKMgSBCu		1.47	0.13	0.43 b	*0.13* b	0.09 b	0.13	20	*2*	

Means followed by a different letter are significantly different within an incremental period using Duncan's Multiple Range Procedure at the 5% alpha level.

† Foliar nutrients in *italics* are at or below sufficiency for loblolly pine (Wells and Crutchfield 1973, Allen 1987, Jokela 2004).

Table 6. Growth parameter means at fertilization (age 15-years-old), two, and four years post application in a thinned old-field loblolly pine plantation in Washington County, Georgia (Orangeburg soil).

Fertilizer treatment	Age (years)	Trees per acre	Dbh (in)	Basal area (ft2/ac)	Height (ft)	Live crown ratio (%)	Volume/ tree (ft^3/ac)	Total volume (ft^3/ac)*	SP ‡ volume (ft^3/ac) *	CNS ‡ volume (ft^3/ac) *
	15									
Control		172	9.31	82.0	56.5	NA	11.7	2034	320	1434
200N+25P		166	9.33	79.8	56.2	NA	11.7	1970	350	1364
200N+25P+50K		172	9.10	78.5	56.1	NA	11.1	1941	444	1239
NPKMgSBCu		168	9.35	80.9	57.2	NA	11.9	2027	276	1464
	17									
Control		172	10.1	96.6	64.1	41	15.4	2668	141	2191
200N+25P		164	10.3	95.1	64.5	42	15.9	2640	168	2160
200N+25P+50K		172	10.0	94.4	64.1	40	15.0	2609	174	2098
NPKMgSBCu		164	10.2	94.1	66.1	42	16.1	2669	88	2242
	19									
Control		168	11.0	113	70.5	45	19.8	3367	60	2438
200N+25P		164	11.2	114	69.9	45	20.3	3376	39	2230
200N+25P+50K		172	11.0	114	69.5	42	19.3	3358	17	2414
NPKMgSBCu		160	11.2	111	71.7	43	20.6	3347	84	2420

‡ PW = pulpwood; trees wit ha dbh of 4.6 to 6.5 inches (no pulpwood sized trees in this case study), SP = superpulp; trees with a dbh of 6.6 to 8.5 inches, and CNS = chip-n=saw trees with a dbh > 8.5 inches.
* ft^3/ac = cubic feet per acre; 88 ft^3 = 1 cord of wood+bark, and 100 ft^3 ≈ 3 tons.

Table 7. Growth parameter increment means between at fertilization and two years post-fertilization (age 15 through 17-years-old), between two and four years post-fertilization (age 17 through 19-years-old), and between at fertilization and four years later (ages 15- through 19-years-old) in a thinned old-field loblolly pine plantation in Washington County, Georgia (Orangeburg soil).

Fertilizer treatment	Age (years)	Trees per acre	Dbh (in)	Basal area (ft^2/ac)	Height (ft)	Volume/ tree (ft^3/ac)	Total volume (ft^3/ac)*	SP‡ volume (ft^3/ac) *	CNS ‡ volume (ft^3/ac)*
	15 – 17								
Control		0	0.79	14.6	7.58	3.63	634	-179	757
200N+25P		-2	0.92	15.3	8.33	4.18	669	-182	797
200N+25P+50K		0	0.88	15.9	7.95	3.83	668	-270	859
NPKMgSBCu		-4	0.88	13.2	8.90	4.22	642	-189	778
	17 – 19								
Control		-4	0.92	16.4	6.43	4.42	699	-81	247
200N+25P		0	0.98	19.1	5.43	4.40	737	-129	70
200N+25P+50K		0	1.00	19.7	5.45	4.34	749	-157	317
NPKMgSBCu		-4	0.98	16.8	5.55	4.48	678	-4	177
	15 – 19								
Control		-4	1.72	31.0	14.0	8.05	1333	-260	1004
200N+25P		-2	1.90	34.4	13.8	8.58	1406	-311	1175
200N+25P+50K		0	1.88	35.6	13.4	8.17	1417	-427	956
NPKMgSBCu		-8	1.86	29.9	14.5	8.70	1320	-192	866

‡ PW = pulpwood; trees with a dbh of 4.6 to 6.5 inches (no pulpwood sized trees in this case study), SP = superpulp; trees with a dbh of 6.6 to 8.5 inches, and CNS = chip-n=saw trees with a dbh > 8.5 inches.
* ft^3/ac = cubic feet per acre; 88 ft^3 = 1 cord of wood+bark, and 100 ft^3 ≈ 3 tons.
\# growth increment means followed by a different letter are significantly different within an incremental period using Duncan's Multiple Range Procedure at the 5% alpha level. There were no significant treatment differences.

Discussion

The study area soils and pre-application soil and foliar nutrient status

This study area was on a soil with good physical properties (% sand, silt, clay, drainage, and depth to argillic) to grow loblolly pine. The study area was farmed mostly in corn, prior to being planted in loblolly pine. Based on established soil available P critical level of <10 lbs/acre, none of the fertilizer treatment plots mean soil P was at or below critical prior to fertilizer applications (Table 3). The control had an average of 22 lbs available-P/acre, NP had 21 lbs/acre, NPK had 12 lbs/acre, and the complete fertilizer plots mean was 18 lbs/acre (Table 3). Based on foliar sufficiency guidelines (Table 2), foliar P was below (0.10 and 0.11 % for the control, NP, and complete treatments) or at sufficiency (0.12 % for the NPK plots) prior to fertilizer application (Table 4). Foliar K was at sufficiency for the control plot mean. Foliar B and Cu were also at or below sufficiency for all treatment plot means prior to treatment (Table 4). Foliar N was above sufficiency for all treatment means.

Site factors and post-application nutrient status, LAI, and growth findings

Due to several site and stand factors, this site did not respond significantly to NP, NPK, NPKMgSBCu fertilization over the 4-year study period.

►The site factors are: (1) the site was formerly in annual crops with relatively little hardwood competition when the stand was thinned (the hardwood component is increasing since the thinning), (2) the site has a history of being fertilized prior to being planted in trees and nutrient status was better than most cut-over sites.

►Post-application foliar N concentrations were above sufficiency for the control and all fertilizer treatments throughout the study period. Foliar N means were not statistically different between the unfertilized control and the fertilizer treatments throughout the study period. One may conclude that there was no large foliar N benefit to adding 200 lbs N per acre (with P, PK, or PKMgSBCu) on this site at this point in time. Only foliar Cu was at or below sufficiency throughout the study period for the control and fertilizer treatments.

►Leaf area index (LAI) estimates taken in August 2003 (2-years after the fertilizers were applied) indicate that the trees responded well to the thinning (when compared to LAI estimates of 2.25 across all plots in 2000-2001). The average LAI for the control plots was 3.24, while the mean LAI for the three fertilizer treatments was 3.27 two years after fertilization. Since LAI estimates are highly correlated to current annual increment, one should expect a growth rate of 3.25 to 3.75 cords/ac/yr or more during this period in the control and fertilized plots.

► The mean annual increment (MAI) for the control plot loblolly pine was 333 ft^3/acre/yr (3.79 cds/ac/yr or 10.5 tons/ac/yr). This MAI for the unfertilized plots is 3.5% less than the average MAI for the fertilized plots over the 4-year period. Essentially, if a NIPFL can grow loblolly pine at a rate of 3.79 cds/ac/yr (10.2 tons/ac/yr) the first 4 years after a thinning without fertilization, then he/she is not going to do much better with fertilization (i.e. no macro-on micro-nutrients are limiting loblolly pine growth at this point in time).

Recommendations

To determine if a pine plantation will respond to fertilization use the well established diagnostic tools for fertilization: (1) LAI estimation (for N needs, done during peak leaf area commonly in July-August), (2) soil sampling for available P, (3) foliage sampling (for N, P, K, Ca, Mg, S, B, and Cu, done during the dormant season) and knowledge of soil series present on the site. Other important factors are: pine species, age, stocking, basal area, live crown ratio, presence of insects or disease (southern pine, black, or ips beetles, stem fusiform rust, annosus root rot, pitch canker), % hardwood component, years to thinning or harvest, pine genetics, land use history (old-field, cut-over, pasture), depth to bedrock, fragipan or pan, and water holding capacity/drainage.

Literature Cited:

Allen, H.L. 1987. Forest fertilizers: nutrient amendment, stand productivity, and environmental impact. Journal of Forestry Volume 85: 37-46.

Blevins, D.; H.L. Allen; S. Colbert; W. Gardner. 1996. Woodland owner notes – Nutrient management for longleaf pine straw. North Carolina Cooperative Extension Service – NCSU, Raleigh, NC. WON-30. 8 p.

Jokela, E.J. 2004. Nutrient management for southern pines. In: Dickens, E.D.; Barnett, J.P.; Hubbard, W.G.; Jokela, E.J. eds. Slash pine: still growing and growing! Proceedings of the slash pine symposium. Gen. Tech. Rep. SRS-76. Asheville, NC. USDA Forest Service, Southern Research Stn: 27 – 35.

Pritchett, W.L.: Comerford, N.B. 1983. Nutrition and fertilization of slash pine. In: Stone, E.L. ed. The managed slash pine ecosystem. June 9-11, 1981; Gainesville, FL; School of Forest Resources and Conservation, Univ. of FL: 69 - 90.

Wells, G.C.; Crutchfield, D.M.; Berenyi, N.M.; Davey, C.B. 1973. Soil and foliar guidelines for phosphorus fertilization of loblolly pine. Res. Paper SE-110. Asheville, NC. USDA Forest Service So

CITATION

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Athens, Georgia 30602-2152
Phone: 706.542.6819 • fax: 706.542.5073