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**Loblolly Pine Stand Fertilization at Mid-rotation
to Increase Small and Large Sawtimber Volume**

2008 Summary Report GA 26-F (UGA acct #2131RE273142)

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Case Study

The UGA Warnell School of Forestry and Natural Resources (WSFNR) installed a replicated fertilizer study on Chuck Leavell's Charlene Plantation, located in near Bullard (Twiggs County), Georgia. Seven of nine thinned loblolly pine stands on Chuck's property show NP, NPK, NPkS, or NPKSCu deficiencies based on soil and foliar sampling on 27 February 2004. Leaf area index (LAI) estimation taken in July 2004 showed that these nutrient deficient stands had LAIs below optimal levels indicating a good probability of response to N.

Objectives

The WSNFR (David Dickens and Bryan McElvany) and Cooperative Extension Service county agent installed two fertilizer trials using fertilizer treatments and an untreated control (planted in 1978, thinned in 2002-03). These marginal fertility stands are the Bullard Bluff East tract (8 plots; 2 replications of 3 fertilizer treatments and a control) and the Bullard Bluff West tract (15 plots; 3 replications of 4 fertilizer treatments and a control). The major objectives: (1) quantify the magnitude and duration of wood volume response to the fertilizer combinations, (2) determine changes in product class distribution and (3) the cash flow and rate of return for each fertilizer combination compared to unfertilized control plots, and (4) discern when fertilizers are to be re-applied to maintain wood volume gain.

Project Layout and Experimental Design

Gross treated plots (147.6 x 147.6 feet, or 0.5 acres) and internal permanent measurement plots (104.5 x 104.5 feet or 0.25 acres) were installed between July and December 2004. Soil pH and available (Mehlich I) nutrient status were estimated during this period. Forty feet of untreated buffer is between each gross treated plot. Replications (blocks) were laid out on the basis of contour to minimize soil moisture differences and basal area to balance stocking/size differences. Baseline soil (10 core samples to make a composite sample, with one composite sample /plot @ 0-6") were taken in each plot prior to treatment and annually post-treatment. All living crop trees in each plot were aluminum tagged, numbered and measured for dbh, total height, live crown length, and defect(s) prior to treatment (January 2005), two and four years post treatment.

Randomly assigned to each plot was NP, NPK, NPKSCu (Bullard Bluff East; BBE) or NP, NPCu, NPKCu, NPKSCu (Bullard Bluff West; BBW) fertilizer treatments. Untreated control plots will serve reference plots. The one-time fertilizer application levels in the thinned loblolly pine stand were applied on 15-16 February 2005. Fertilizer levels were: 200 lbs N/acre + 50 lbs elemental-P + 80 lbs elemental-K + 60 lbs S and 5 lbs Cu/acre. Rainfall patterns were excellent the first few months since fertilizer application. The first post application rain occurred on 18 February and was 1 ½ inch and 1 inch on 24 February 2005. A low-cost (\$15/ac for product) foliar active herbicide, Glyphosate with a surfactant, was applied at a rate of 3 qts/ac with an ATV and boomless sprayer @ 15 gpa in August 2004 on BBE (pre-fertilization) and in August 2005 on BBW (post-fertilization).

Plot leaf area index (LAI) is being estimated every other year using the NCSU protocol starting in July 2005. Foliage samples are being taken every other dormant season starting in December 2005. Soil and foliage analysis include N (foliage only), P, K, Ca, Mg, S, Cu, Mn, Zn, and B. Soil pH for each plot is also being determined.

Outcome - Goals

We had two study area field days (1) Chuck Leavell hosting for 15 German foresters on 11 February 2008 and (2) a forest landowner field day with 30 attendees on 16 October 2008 (forest landowners, county agents, GFC foresters, forestry consultants, and study sponsors). Increases in diameter growth, crown and leaf area, volume/acre, and product class and cash flow changes were addressed at these field days. Workshops, seminars, extension publications and other publications will also be generated from these demonstration sites and distributed to the same and made available on the WEB. Also addressed will be various ways for fertilizers to be applied to forest stands with tractor-spreader combinations (cyclone or pull behind), spreader calibration, how much urea, DAP, muriate of potash, S, and Cu to apply per acre, and when to apply fertilizers for maximum benefit and minimum losses. It is anticipated that many forest landowners will be able to make educated and informed fertilization decisions in thinned loblolly pine plantations from this project.

Results for the Bullard Bluff West Study Area

Growth treatment means were tested using SAS, ANOVA, and Duncan's Multiple Range test at the 5% alpha level for significant differences. Soil and foliar nutrient levels have not been tested for significant differences for this report.

Soil

Pre-application pH on the study area plots ranged from 5.3 to 5.6 (Table 1). Soil available P ranged from 4 to 12 lbs/ac (sufficiency is considered to be > 12 lbs/ac) prior to treatment. Soil available K ranged from 32 to 47 lbs/ac, Ca ranged from 332 to 757 lbs/ac, and Mg ranged from 39 to 67 lbs/ac (Table 1) prior to treatment.

First year post-treatment soil pH ranged from 5.0 to 5.4 with declines of 0.2 to 0.4 units on the fertilizer treatment plots (Table 2). Available P increased by 14 - 20 lbs/ac to above sufficiency (18 - 24 lbs/ac) in the fertilizer treatment plots one year after treatment; YAT (Table 2). Available K increased by 33 - 41 lbs/ac in the fertilizer treatments that had K between January 2005 and February 2006 (Table 1 and 2).

Foliage

Loblolly pine foliar N concentrations were above sufficiency (1.2% N) prior to treatment (January 2005, Table 3). Pr-treatment foliar P concentrations ranged from below sufficiency (0.12% for loblolly pine) for the control (0.10%), to at sufficiency for the NP, NPKCu, and NPKSCu treatments, and above sufficiency (0.13%) for the NPCu treatment (Table 3). There were significant pre-treatment foliar K concentration differences with the control (0.38%) being significantly less than the NP (0.51%), NPCu (0.46%), and NPKSCu (0.50%). Foliar Ca, Mg, and S were above sufficiency (0.30%, 0.15%, and 0.10%, respectively) prior to fertilizer application for all treatments (Table 3). Foliar Cu was at or below sufficiency (2-3 ppm) for all treatments in January 2005 (Table 3).

First year post-application loblolly pine foliar N was above sufficiency for all treatments, slightly above for the control and well above for the fertilizer treatments (Table 4). Foliar P levels ranged from slightly below sufficiency for the NPCu and NPKSCu (0.11%) to at sufficiency for the control, NP, and NPKCu (0.12%) treatments 1 YAT (Table 4). Foliar K, Ca, and Mg were above sufficiency for all treatments 1 YAT. Foliar Cu ranged from 1.5 ppm (NPKCu) to 2.4 ppm (NPKSCu) 1 YAT (Table 4).

Table 1. Pre-application (Jan 2005) soil pH, available (Mehlich I) P, K, Ca, and Mg from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	pH	P	K	Ca	Mg
		----- lbs/acre -----			
Control	5.4	8	42	472	49
NP	5.6	7	47	757	67
NPCu	5.3	12	44	396	52
NPKCu	5.3	4	32	332	39
NPKSCu	5.5	4	38	506	54

Table 2. One-year post-application (Feb 2006) soil pH, available (Mehlich I) P, K, Ca, and Mg means from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	pH	P	K	Ca	Mg
		----- lbs/acre -----			
Control	5.4	10	42	401	49
NP	5.3	24	46	500	49
NPCu	5.1	24	37	321	35
NPKCu	5.0	24	65	281	32
NPKSCu	5.1	18	79	350	35

Table 3. Pre-application (Jan 2005) foliage M, P, K, Ca, Mg, S, and Cu concentrations from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	N	P	K	Ca	Mg	S	Cu
	----- percent -----						ppm
Control	1.29	0.10	0.38 c	0.19	0.13	0.12	2.1
NP	1.42	0.12	0.51 a	0.25	0.14	0.14	2.0
NPCu	1.43	0.13	0.46 ab	0.20	0.17	0.14	1.8
NPKCu	1.47	0.12	0.40 bc	0.22	0.15	0.14	2.2
NPKSCu	1.48	0.12	0.50 a	0.24	0.15	0.15	2.2

Table 4. One-year post-application (Feb 2006) foliage M, P, K, Ca, Mg, S, and Cu concentrations from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	N	P	K	Ca	Mg	S	Cu
	----- percent -----						ppm
Control	1.21	0.12	0.40	0.23	0.13	0.11	2.3
NP	1.60	0.12	0.40	0.21	0.11	0.13	2.1
NPCu	1.42	0.11	0.42	0.20	0.12	0.14	1.9
NPKCu	1.54	0.12	0.48	0.24	0.11	0.14	1.5
NPKSCu	1.40	0.11	0.41	0.20	0.11	0.15	2.4

Two-year growth results

There was a significant difference in two-year volume per tree increment worth noting. The control plot loblolly pine trees grew an average of 2.0 cubic feet, significantly less than the NP treatment (3.0 cubic feet or 50% more volume) and the NPKCu treatment (2.6 cubic feet or 30% more volume, Table 7). Although not significant, other growth increment differences are of interest; control plot loblolly pine mean height increment was 3.4 feet, whereas the NP treatment was 5.1 feet (50% greater height increment) and the NPCu, NPKCu, and NPKSCu grew 4.9, 4.8 and 4.7 feet, respectively for the two-year period (Table 5). Total volume per acre growth increments were 323 cubic feet for the control to 449 cubic feet for the NPKCu treatment, a 39% gain in two years (Table 6).

Discussion

It is too early to pass major judgment on two-year findings for a crop with a 30- to 40-year rotation, but some trends are showing promise. Mean height increment, volume per tree and volume per gains are large to just a two-year period. We will know more after our 4-year measurements this 28-29 January 2009 where fertilizer gains (diameter and volume) typically tend to peak. We may achieve a later peak gain, possibly in year 6, due a herbicide being applied in the same 12 month period as the fertilizer treatment. Mid-rotation herbicide responses tend to peak 8 years post application.

Table 5. Pre- and one year post-application trees/acre, diameter at 4.5 feet (dbh), height and live crown ratio means from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	Trees per acre	Trees per acre	Trees per acre	DBH	DBH	DBH	Height	Height	Height	Live Crown Ratio	Live Crown Ratio	Live Crown Ratio
	2005	2007	2005-2007	2005	2007	2005-2007	2005	2007	2005-2007	2005	2007	2005-2007
				(in)	(in)	(in)	(ft)	(ft)	(ft)	(%)	(%)	(%)
Control	176	175	-1	9.7	10.1	0.4	58.1	61.6	3.4	43	41	-2
NP	141	139	-3	10.4	11.0	0.6	57.8	62.9	5.1	47	44	-3
NPCu	181	181	0	9.7	10.1	0.4	59.6	64.5	4.9	44	41	-3
NPKCu	156	156	0	9.8	10.3	0.5	57.6	62.4	4.8	45	43	-2
NPKSCu	167	167	0	9.7	10.2	0.5	59.4	64.2	4.7	42	40	-3

Table 6. Pre- and two year post-application basal area, total volume, pulpwood and superpulp volume means from the cut-over, thinned loblolly pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	Basal area per acre 2005	Basal area per acre 2007	Basal area per acre 2005-2007	Total Volume 2005	Total Volume 2007	Total Volume 2005-2007	Pulpwood Volume 2005	Pulpwood Volume 2007	Pulpwood Volume 2005-2007	Superpulp Volume 2005	Superpulp Volume 2007	Superpulp Volume 2005-2007
	(ft ²)	(ft ²)	(ft ²)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)	(ft ³ /acre)
Control	94	101	7	2393	2717	323	13b	13	0a	361	251	-111
NP	86	95	8	2171	2549	378	0b	0	0a	147	64	-83
NPCu	96	104	8	2527	2936	409	45a	24	-21b	389	311	-78
NPKCu	82	93	11	2068	2517	449	18b	3	-15b	221	173	-49
NPKSCu	87	96	9	2290	2681	391	16b	19	3a	310	240	-71

Table 7. Pre- and two year post-application basal area, total volume, pulpwood and superpulp volume means from the cut-over, thinned loblolly

pine (planted in 1978) Bullard Bluff West stand on Charlane Plantation, Twiggs County, GA (Orangeburg soil series)

Treatment	Volume per tree 2005 (ft ³)	Volume per tree 2007 (ft ³)	Volume per tree 2005- 2007 (ft ³)	Total PW Volume 2005 (ft ³ /acre)	Total PW Volume 2007 (ft ³ /acre)	Total PW Volume 2005- 2007 (ft ³ /acre)	Chip-N- Saw Volume 2005 (ft ³ /acre)	Chip-N- Saw Volume 2007 (ft ³ /acre)	Chip-N- Saw Volume 2005- 2007 (ft ³ /acre)	Sawtimber Volume 2005 (ft ³ /acre)	Sawtimber Volume 2007 (ft ³ /acre)	Sawtimber Volume 2005- 2007 (ft ³ /acre)
Control	13.6	15.5	2.0c	374	264	-111	1455	1721	267	271	395	125
NP	15.3	18.3	3.0a	147	64	-83	1439	1609	169	317	564	247
NPCu	14.0	16.3	2.3bc	434	335	-99	1436	1787	351	358	464	106
NPKCu	13.6	16.1	2.6ab	239	176	-63	1369	1678	310	193	349	157
NPKSCu	13.9	16.2	2.4bc	326	258	-68	1491	1719	227	193	375	182