LONGLEAF PINE WOOD AND STRAW YIELDS FROM TWO OLD-FIELD PLANTED SITES IN GEORGIA

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ABSTRACT

Little is known or published concerning longleaf pine's growth rate, or wood and pine straw yields on old-field sites. Two study areas were installed in unthinned longleaf plantations established on former old-fields in Screven and Tift Counties, Georgia to address pine growth and straw yields. Soil series were delineated and replicated plots with three levels of fertilization (control = no fertilizer, a NPK single dose, and a NPK split dose) were imposed at each site. This paper will focus on longleaf pine stand growth and wood yields through age 21-years and pine straw yields through age 23-years. The results indicate that these two old-field longleaf pine stands without fertilization were growing at a rate of 203 cubic feet per acre per year at Tift County site and 221 cubic feet per acre per year at the Screven County site through age 21-years. Mean annual increments for all treatments at both sites were increasing from age 17- through age 21-years. Mean dbh values ranged from 8.8 inches (control at Tift County site) to 9.5 inches (split NPK at the Screven County site) through age 21-years. Mean tree heights through age 21-years ranged from 59.1 feet (single NPK dose at the Screven County site) to 60.8 feet (control and split NPK dose at the Tift County site). Pine straw yields without fertilization averaged 4306 pounds (dry weight) per acre per year from ages 15- through age 23-years at the Screven County site and 3764 pounds per acre (dry weight) at the Tift County site from ages 17- though 23-years. Fertilization did not significantly improve longleaf pine growth parameters during the reported study period. Pine straw yields were significantly improved with fertilization at both sites generally two and three years after application becoming non-significant compared to the control in the fourth year after treatment.

INTRODUCTION AND OBJECTIVES

Approximately 203,500 acres of old-field sites in Georgia have been planted to longleaf pine from 1999 through 2010 (Weaver 2011). Little is known of the upper end of longleaf pine growth rate and wood and pine straw yields on old-field sites. Most old-field sites have a large fertility reserve, essentially no competing hardwoods and good surface soil tilth. Accelerated growth rates for loblolly and slash pine have been noted in Georgia during first 10- to 20-years on these old-field sites. The main objectives of this study on old-field sites were to: (1) determine the growth rate and wood yields of longleaf pine, (2) estimate pine straw yields, and (3) quantify the benefit of fertilization with a single or split application of nitrogen, phosphorus, and potassium. Pre-treatment longleaf pine growth means at the end of the 17th growing season (December 2003, February 2004) and the end of the 21st growing season and pine straw yields through age 23-years are reported in this paper.

MATERIALS AND METHODS

Two study areas were installed in unthinned longleaf plantations established on former old-fields in Screven and Tift Counties, Georgia. Bareroot (replications 1 and 2) and containerized seedlings (replications 3 and 4) were planted at the Screven County site and bareroot seedlings (all replications) were planted at the Tift County site. Both sites were planted at an approximate 6 feet by 12 feet spacing (605 seedlings per acre). The Screven County site was terraced and subsoiled prior to planting, mowed between the rows two times per year for the first five years post plant, and burned four times from age 8-years-old to age 21-years old. The Tift County site was chisel plowed prior to planting then Oust® (DuPont; 75 percent sulfometuron methyl) was sprayed in years one and two post-plant, burned (backing fire, accidentally) in year two, prescribe burned in years five and seven, pruned in year eight, and spot raked starting in year 10. The soil series were delineated by a Natural Resource Conservation Service soil mapper as Blanton (well drained, fine sand Grossarenic Paleudult) and Bonneau (well drained, loamy sand Arenic Paleudult) at the Screven County site and Albany (somewhat poorly drained, sandy Aquic Arenic Paleudult) and Leefield (somewhat poorly drained, loamy sand Arenic Plinthaquic Paleudult) at the Tift County site. Baseline soil (0-6") and foliage samples were collected in December 2003 at the Screven county site and in February 2004 at the Tift county site. Surface soil (0-6 inches) available phosphorus (P) levels averaged 11 lbs/ac (5 to 19 lbs/ac range) and a mean soil pH of 5.8 (5.4 to 6.2 range) at the Screven County site prior to treatments. Surface soil (0-6 inches) available phosphorus (P) levels averaged 18 lbs/ac (5 to 38 lbs/ac range) and a mean soil pH of 4.8 (4.6 to 5.0 range) at the Tift County site prior to treatments. Longleaf pine foliar nitrogen, phosphorus, and potassium concentration means were 1.14 (0.971 to 1.52

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range) percent, 0.10 (0.09 to 0.15 range) percent, and 0.43 (0.29 to 0.57 range) percent, respectively prior to treatments at the Screven County site. Longleaf pine foliar nitrogen (N), phosphorus, and potassium (K) concentration means were 0.91 (0.73 to 1.1 range) percent, 0.095 (0.066 to 0.12 range) percent, and 0.37 (0.32 to 0.42 range) percent, respectively prior to treatments at the Tift County site. Mean surface soil available P levels were above sufficiency (6 to 10 lbs/ac P; Wells et al. 1973) at both locations prior to treatments. Mean longleaf foliar N, P, and K concentrations (Blevins et al. 1996, Dickens and Moorhead 2006) were above sufficiency (0.95, 0.08, and 0.25 to 0.30 percent for longleaf pine, respectively) at the Screven County site and above sufficiency for P and K at the Tift County site but slightly below sufficiency for N prior to treatments.

A randomized complete block experimental design was used at both locations. There were three (Tift County) or four (Screven County site) replications of each treatment per study area. Gross treated (1/4 acre) plots were installed with a 1/10th acre internal permanent measurement plots (IPMP). There were 40 feet of untreated buffer between each plot. Treatments included: (a) control (Control; no fertilization), (b) a full dose of NPK (full NPK; DAP+urea+muriate of potash; 150 N, 50 elemental-P and 50 elemental-K lbs/ac), and (c) a split (half + half) dose of NPK (split NPK; 75 N + 25 elemental-P + 25 elemental-K lbs/ac/application as DAP+urea+muriate of potash) with the first application applied in mid-February 2004 (both full and half dose treatments). The second half dose of the split dose treatment was applied in February 2007 to the split dose plots.

Each living tree in the IPMP was aluminum tree tagged, numbered, and measured for diameter at breast height (dbh; or 4.5 feet above groundline, measured with diameter tapes to nearest 1/10th inch), total height (measured with a Haglof Vertex II Laser Hypsometer), height to base of live crown, and fork or broken top in December 2003 for the Screven County site and February 2004 for the Tift County site prior to treatments, in January 2006, January 2008, and January 2010. Visible stem defects, including a fork or broken top, sweep greater than 3 inches in any 10 feet stem length, ramicorn branch, excessive branching (> 6 branches per linear foot) or branch base diameters greater than 2.5 inches were noted for each tagged tree at each site at the end of the 17th growing season and 23rd growing season. A single glyphosate herbicide with a surfactant was used one-time in mid-summer 2004 on all study area plots to keep the stand clean for straw production. Planted longleaf volume equations from Baldwin and Saucier (1983); log (total tree wood+bark volume) = -2.552214 + 0.99928 log (dbh^2 * total height) where dbh was in inches, height in feet, and volume in cubic feet were used to estimate total volume per tree, total volume per acre, and total volume per acre mean annual increment on these old-field stands. Pine straw (litter layer only collected) yields were estimated in each plot from four 16 square feet angle iron grids annually at the Tift County site and periodically at the Screven County site (as variable operational raking regimes made for unreliable annual pine straw yields). The litter layer from each grid were collected, bagged, field weighed, oven dried for 48 hours at 60^{o} C, dry weighed and converted to dry weight per acre. Stand parameters (trees per acre, dbh, basal area, height, live crown ratio, total volume per tree, and total volume per acre and pine straw yields treatment means for each measurement year at each site were tested for significant differences using Duncan's Multiple Range Test at the five percent alpha level using the SAS® STATS package Version 9.2 (SAS® 2010).

RESULTS

There were no significant treatment differences for longleaf pine growth parameters at the Screven County site (Table 1 and 3) or the Tift County site (Table 2 and 4) during the study period. Mean trees per acre ranged from 303 to 360 at age 17-years (Table 1 and 2). In unfertilized plots through age 21-years, mean trees per acre were 303 at both the Screven and Tift County sites, approximately one-half of the original planting stocking level. Mean diameters at 4.5 feet above groundline (dbh) ranged from 7.96 inches to 8.47 inches at age 17-years and 8.80 to 9.52 inches by age 21-years (Table 1 and 2). Basal areas at age 17-years ranged from 113 to 127 square feet per acre and from 125 to 146 square feet per acre by age 21-years (Table 1 and 2). Estimated longleaf pine total volume (stemwood+bark) yields ranged from 3096 (split NPK at the Tift County site) to 3845 cubic feet per acre (full NPK at the Tift County site) and from 4261 (control at the Tift County site) to 5245 cubic feet per acre (full NPK at the Tift County site) by age 21-years (Table 2 and 4). Mean annual increments through age 17-years ranged from 186 (control at the Tift County site) to 226 cubic feet per acre per year (full NPK at the Tift County site) at age 17-years and 203 (control at the Tift County site) to 250 cubic feet per acre per year (full NPK at the Tift County site) by age 21-years (Table 3 and 4).

Pine straw yields without fertilization averaged 4308 pounds per acre per year at the Screven County site and 3764 pounds per acre per year at the Tift County site (Table 5 and 6). Pine straw yields were significantly increased with fertilization by age 19-years, two years after the initial split NPK treatment and full NPK treatment (applied one-time) at the Screven County site (4878, 6248, and 6459 pounds per acre for the control, ½+½ NPK, and full NPK treatment, respectively; Table 5). The mean pine straw yields from the split NPK treatment tree plots were significantly greater than the control at age 20- and 23-years (3811 compared to 4715 pounds per acre and 3760 compared to 4423 pounds per acre for the control and split NPK treatment at age 20- and 23-years, respectively; Table 5). The mean pine straw yields from the full (one-time) NPK treatment were not significantly greater than the control at age 20- or 23-years at the Screven County site. Mean pine straw yields from the split NPK treatment and full NPK treatment were approximately 550 and 380 pounds per acre year greater than the control, respectively, from age 15- through 23-years at the Screven County site (Table 5). Pine straw yields were significantly increased with the full NPK treatment compared to the control (5560 and 4591 pounds per acre, respectively) at age 19-years, two years after treatment at the Tift County site and at age 20-years (4613 and 3443 pounds per acre, respectively, Table 6). Pine straw yields from the full NPK treatment plot trees were not significantly different than the control at ages 21-, 22- and 23-years at the Tift County site (four, five, and six years after the one-time application; Table 6). Pine straw yields from the split NPK treatment plot trees were significantly greater than the control at age 20- (5311 versus 3443 pounds per acre), 21- (3395 versus 2295 pounds per acre), and 22-years (4658 versus 4199 pounds per acre) but not significantly different at age 23-years (Table 6) at the Tift County site. Mean pine straw yields from the split NPK treatment and full NPK treatment were approximately 500 and 330 pounds per acre year greater than the control, respectively, from age 17- through 23-years at the Tift County site (Table 6).

Percent defective trees; trees with a visible stem canker, fork or broken top below 25 feet (one and a half logs with a one foot stump allowance), stem sweep greater than three inches per 10 feet run, or excessive branching (>6 per linear foot), ramicorn, or large (> 2.5 inches branch base diameter) branches starting below 25 feet were noted at each study site across all plots at age 17- and age 21-years. These tallied defective trees, based on our ocular observations, would not make a product class jump from pulpwood into the higher valued product classes of chip-n-saw, sawtimber, or poles. Percent defective longleaf pines at age 21-years at the Screven County site were estimated to be 50 percent in the control plots (42 to 59 percent range), 37 percent in the split NPK treatment plots (26 to 43 percent range), and 49 percent in the full NPK plots (43 to 59 percent range). Percent defective longleaf pines at age 21-years at the Tift County site were estimated to be 43 percent in the control plots (36 to 50 percent range), 47 percent in the split NPK treatment plots (38 to 50 percent range), and 47 percent in the full NPK plots (43 to 52 percent range). With an overall defect average of 46 percent at both study areas through age 21-years and an average of 294 and 321 trees per acre at the Screven and Tift County sites, this equates to 135 and 148 final crop trees per acre, respectively, if all defective trees are removed in the first thinning.

DISCUSSION AND CONCLUSIONS

The estimated growth rates of 203 and 221 cubic feet per acre per through age 21-years, without fertilization, in these two old-field longleaf pine stands is greater than the 164 cubic feet per acre per year growth rate for the high site index longleaf through age 20-years reported by Goelz and Leduc (2001). The longleaf pine growth parameter responses to the ½+½ NPK or full NPK fertilizer treatments were not significantly greater than the control over the four year study period. Single dose fertilization (N+P) studies on loblolly pine indicate that fertilization response typically peaks four years after application (Hynynen et al. 2000), yet in these studies on longleaf pine the benefit to fertilization was not realized through four years post-treatment. The lack of longleaf pine growth response to fertilization is most likely due to the fact that these two sites were former old-fields in annual crops with moderate to high residual nutrient availability. There was a significant pine straw response to the fertilizer treatments usually occurring two years after application and lasting into year three or four post treatment. The estimated percent defective trees in each study area averaged 46 percent after 21-years may be due to a number of factors; no genetically improved longleaf seedlings available for planting for these two study sites in 1986, the original rectangular spacing (6 feet by 12 feet; with more and larger branches growing into the rows compared to the branches growing in between the trees above 16 feet), the relatively low stocking by age 21-years for longleaf pine, and the fast growth rate. The number and intensity of fires in each stand may have aided in lower (first ½ log or below 8 to 9 feet) stem pruning but by age 21-years most of first ½ to full log branches (number and size) were not the issue in a tree being defective.

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LITERATURE CITED

Baldwin, V. and Saucier, J.R. 1983. Aboveground weight and volume of unthinned, planted longleaf pine on West Gulf forest sites. Res. Pap. SO-191. New Orleans, LA: USDA Forest Service, Southern Forest Exp Stn. 25 p.

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

Dickens, E.D. and Moorhead, D.J. 2006. Sampling loblolly, longleaf, and slash pine foliage for nutrient analysis. http://www.bugwood.org/fertilization/foliage.html . 4 p.

Goelz, J.C.G. and Leduc, D.J. 2001. Long-term studies in development of longleaf pine plantations. In: Kush, J.S., compl. Forest for your future – restoration and management of longleaf pine ecosystems; Silvicultural, ecological, social, political, and economic changes. Proceedings of the 3rd Longleaf Alliance Regional Conf. 2000. Alexandria, LA. Longleaf Alliance Report No. 5: 116-119.

Hynynen, J., Burkhart, H.E., and Allen, H.L. 1995. Modeling tree growth in fertilized midrotation loblolly pine plantations. Report No. 80. School of Forestry and Wildlife Resources. VPI & SU. Blacksburg, VA. 35 p.

SAS. 2010. Statistical Analysis Software. Version 9.2. Cary, NC. Weaver, C.E. 2011. Longleaf Conservation Reserve Program statistics for Georgia. Farm Service Agency, Athens, GA.

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 Southern Research Stn.

Table 1—Trees per acre, diameter at breast height (dbh or 4.5 feet above groundline), basal area, and height for December 1986 unthinned, old-field planted longleaf pine plots at the Screven County, Georgia site (Bonneau and Blanton soils) through age 17- and 21-years-old

	Trees per acre		dbh (inches)		Basal area (ft^2/ac)		Height (feet)	
Treatment	---------- Age (years) ----------							
	17	21	17	21	17	21	17	21
Control	325	303	8.37	9.24	121	135	50.4	60.1
Split NPK	303	273	8.47	9.52	114	125	49.9	59.9
Full NPK	328	305	8.32	9.24	120	136	49.3	59.1

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level. Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.

Table 2—Trees per acre, diameter at breast height (dbh or 4.5 feet above groundline), basal area, and height for December 1986 unthinned, old-field planted longleaf pine plots at the Tift County, Georgia site (Albany and Leefield soils) through age 17- and 21-years-old

	Trees per acre		dbh (inches)		Basal area (ft^2/ac)		Height (feet)	
Treatment	---------- Age (years) ----------							
	17	21	17	21	17	21	17	21
Control	320	303	7.97	8.80	114	126	52.1	60.8
Split NPK	317	310	7.96	8.84	113	129	51.6	60.8
Full NPK	360	350	8.26	9.09	127	146	52.4	60.7

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level. Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.

Table 3—Live crown ratio, volume per tree, and volume per acre for December 1986 unthinned, old-field planted longleaf pine plots at the Screven County, Georgia site (Bonneau and Blanton soils) through age 17- and 21-years-old

	Live crown ratio (percent)		Total volume per tree (ft^3)		Total volume per acre (ft^3)		Mean annual increment: MAI (ft^3/ac/yr)	
Treatment	---------- Age (years) ----------							
	17	21	17	21	17	21	17	21
Control	43.0	39.7	10.5	15.3	3428	4643	202	221
Split NPK	45.1	43.4	10.7	16.2	3240	4426	191	211
Full NPK	43.6	39.8	10.2	15.1	3344	4596	197	219

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level (MAI treatments were not tested). Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.

Table 4—Live crown ratio, total volume per tree, total volume per acre, and mean annual increment for December 1986 unthinned, old-field planted longleaf pine plots at the Tift County, Georgia site (Albany and Leefield soils) through age 17- and 21-years-old

	Live crown ratio (percent)		Total volume per tree (ft^3)		Total volume per acre (ft^3)		Mean annual increment: MAI (ft^3/ac/yr)	
Treatment	------------------ Age (years) ------------------							
	17	21	17	21	17	21	17	21
Control	47.5	44.7	9.89	14.1	3164	4261	186	203
Split NPK	49.6	41.9	9.77	14.2	3096	4399	182	210
Full NPK	50.2	41.8	10.7	15.0	3845	5243	226	250

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level (MAI treatments were not tested). Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.

Table 5—Pine straw yields for December 1986 unthinned, old-field planted longleaf pine plots at the Screven County, Georgia site from age 15- through age 23-years

Treatment	---------- Age (years) ----------					Mean yield
	15	18	19	20	23	
	---------- Pounds per acre (dry weight) ----------					(lbs/ac/yr)
Control	4119	4971	4878 b	3811 b	3760 b	4308
Split NPK	3768	5172	6248 a	4715 a	4423 a	4865
Full NPK	3634	5080	6459 a	4401 ab	3781 b	4689

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level. Mean yields were not tested. Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.

Table 6—Pine straw yields for December 1986 unthinned, old-field planted longleaf pine plots at the Tift County, Georgia site from age 17- through age 23-years

Treatment	---------- Age (years) ----------							Mean yield
	17	18	19	20	21	22	23	
	---------- Pounds per acre (dry weight) ----------							(lbs/ac/yr)
Control	3503	4608	4591 b	3443 b	2295 b	4199 b	3712	3764
Split NPK	3262	4755	5150 ab	5311 a	3395 a	4658 a	3336	4267
Full NPK	3324	4754	5566 a	4613 a	2800 ab	4216 b	3425	4100

Treatment means followed by a different letter within a column are significantly different using Duncan's Multiple Range Test at the five percent alpha level. Mean yields were not tested. Treatments: Control = no fertilization, split NPK = 75 N, 25 elemental-P and 25 elemental-K lbs/ac/application, applied February 2004 and again in February 2007, and full NPK= 150 N, 50 elemental-P and 50 elemental-K lbs/ac applied one-time February 2004.