

Four year growth response results from the demonstration of Best Management Practices (BMPs) for layer litter and inorganic fertilizer applications in an unthinned, old-field slash pine stand in Brantley County, Georgia

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Study area and experimental design

The Brantley County, Georgia site was a former hay-field site of slash pine planted in 1994 on Hurricane and Chipley soils. There were three replications of four treatments in a randomized complete block experimental design. The treatments (Table 1) were:

- (1) no treatment (Control)
- (2) single application of DAP+urea (NP)
- (3) single application of layer litter (One-time litter)
- (4) annual application of layer litter (Annual litter)

Each gross treated plot was ¼ acre with a 1/10 acre internal permanent measurement plot (IPMP) centered within each gross plot. There were 40 feet of untreated buffer between each plot. All living slash pine trees in each IPMP were aluminum tree tagged, numbered, and measured for dbh, total height, and live crown ratio prior to the January 2002 application date, in January 2004 (2-years post first application), and in January 2006 (4-years after the first application). Slash pine growth, soil, and foliage parameter means were tested for significant differences using Duncan's Multiple Range Procedure at the 5% alpha level. Soil and foliage were collected prior to the January 2002 initial application date and annually through February 2005.

Soil and Foliage Results

Mean pre-treatment soil available-P were well above sufficiency (a range of 144 to 206 lbs/ac) for slash pine for all treatment plots (Table 2). There were no significant differences between treatments for soil pH, available P, K, Ca, Mg, Mn, B, Cu, and Zn and total N prior to initial treatments (Table 2). Mean soil pH on 30 October 2001 (pre-application collection date) ranged from 5.3 (NP plots) to 5.6 (one-time and annual litter plots). Post-application soil pH for the control and NP plots were significantly less (4.8 to 5.1) than the one-time and annual litter plots (5.7 to 6.0) in February 2004 and February 2005 (Table 2). The first significant soil difference that occurred was boron in February 2003. The one-time and annual litter soil B was significantly greater than the control (Table 2). Soil available P, K, Ca, and Mg were significantly greater in the annual and one-time litter plots than the control and NP plots two years (February 2004) and three years (February 2005) after the initial application (Table 2). Throughout the study period available P was well above the sufficiency guidelines for slash pine (183 lbs/ac in October 2001 and 148 lbs/ac in February 2005) in the control plots (Table 2).

Foliar N, P, K, Ca, and Mg level means for all treatment plot trees prior to the first treatment date were also above sufficiency (Table 3). Foliar N, P, K, Ca, and Mg concentrations remained above

sufficiency from the control plot trees during the study period. There were no significant differences in foliar N, P, K, Ca, or Mg between the treatments two years after the initial treatment (Table 3). Foliar copper and zinc concentrations were significantly different between treatments in February 2004. Foliar K and B concentrations were significantly greater in the annual litter plot trees than the one-time, NP, and control trees in February 2005 (Table 3). Foliar Zn concentration was significantly less from the annual litter plot trees than the one-time, NP, and control plot trees in February 2005 (Table 3).

Four Year Growth Response Results

There were no significant differences between treatments for trees per acre, mean dbh, basal area, total height, volume per tree, or volume per acre during the four year study period (Table 4).

Pre-application growth parameters

Mean trees per acre ranged from 640 in one-time litter plots to 677 in the annual litter plots (Table 4). Mean dbh ranged from 4.6 (annual litter) to 4.7 (control, NP, and one-time litter plot trees). Basal area prior to the start of the ninth growing season ranged from 73 (one-time litter) to 82 ft²/ac. Total heights ranged from 23.6 feet (annual litter) to 24.4 feet (one-time and annual litter). Volume per tree ranged from 1.61 ft³ (annual litter) to 1.72 ft³ (one-time litter) and volume per acre ranged from 1089 ft³ (annual litter) to 1130 ft³ (Table 4).

Post application two- and four- year growth parameters

Mean trees per acre declined by 16 for the control, 80 for the one-time litter, 90 for the NP (Table 4), and 107 for the annual litter (Table 4). Much of the mortality (59 to 72%) in the litter and NP fertilized plots came after the summer and fall hurricanes of 2004. In most cases, stem cankered trees, forked trees, and trees with large crowns broke or lodged due to the wet soils and high winds. Live crown ratios (LCR) were measured in February 2004 and December 2005. There were no significant LCR's between treatments in these two measurement periods. Live crown ratios ranged from 45% (NP) to 47% one-time litter in February 2004 and 40% (annual litter and NP) to 41% (control and one-time litter) in December 2005 (end of 12 growing seasons). Dbh's ranged from 5.6 (control) to 5.9 inches (one-time litter) two years after initial treatments and 6.3 (control) to 6.7 inches (one-time litter) four years after initial treatments (Table 4). The basal area range was narrow two years after initial treatments; 118 (control, one-time, and annual litter) to 119 ft²/ac (NP). Four year post initial application basal areas ranged from 135 (annual litter) to 146 ft²/ac (control). Total heights ranged from 31.8 feet (one-time litter) to 33.5 feet two years post initial treatment and 40.6 (control) to 41.8 feet (NP) four years post initial treatments. Volume per tree ranged from 3.04 ft³ (control) to 3.35 ft³ (NP) two years after initial application and 4.53 ft³ (control) to 5.12 ft³ (one-time litter) four years after initial application (Table 4). Volume per acre ranged from 1996 ft³ (one-time litter) to 2095 ft³ (NP) two years after initial application and 2765 ft³ (annual litter) to 2985 ft³ (control) four years after initial application (Table 4).

Incremental mortality and growth response to treatments

Tree mortality ranged from 1.9% (control) to 5.2% (one-time litter) during the 2002 through 2004 period (Table 5). Tree mortality during the second measurement period (2004-2006) ranged from 0.5% (control) to 11.9% (annual litter). Tree mortality over the four year study period ranged from 2.4% (control) to 15.8% (annual litter, Table 5). The high levels of mortality from the NP (13.6%), one-time litter (12.5%) and the annual litter (15.8%) over the four year study period is considered excessive and can be attributed to these treatments building large crowns in a short period of time, then hurricane events (wind and saturated soils) caused many of these trees to break at weak points (i.e., stem canker or fork) or lodge.

There was a significant dbh growth increment gain with the NP and one-time litter application over the control during the first measurement period (2002-2004, Table 5). There was no significant dbh growth benefit to the NP, one-time, or annual litter application during the second measurement period (2004-2006) or during the four year study period. There were no significant basal area growth increments over the four year study period (Table 5). In the control plots, average annual

basal area increment during the four year study period was 16 ft²/ac/yr, and there were no significant differences in height growth increment, and volume per tree or volume per acre growth increment over the four year study period (Table 5). Mean annual height increment during the four year study period for the control plot trees was 4.2 feet. Mean annual volume per acre growth increment for the control plot trees was 470 ft³/ac (5.5 cords/ac/yr or 14.7 tons/ac/yr). This is a fast growth rate considering the soils and species.

Summary and Conclusions

This site had a high initial residual fertility level. This high fertility prior to any fertilizer or litter application was evident by (1) high surface soil available-P (14- to 20-fold greater than the minimum guideline of 10 lbs/ac), and (2) foliar N, P, and K concentrations at or above sufficiency for slash pine (1.11% N, 0.16% P, and 0.50% K). This site having a prior land use history of old-field then hay cutting site also had essentially no hardwood competition. Minimal competition allowed the planted slash pines to capture much of the site's resources (sunlight, water, and nutrients).

The rate of growth for slash pine in the untreated plots of 0.40"/yr for dbh, 16 ft²/ac/yr for basal area, 4.2 feet/yr for height, and an overall 2.9 cords/ac/yr mean annual increment (5.5 cords/ac/yr from age 9- through age 12-years) for volume is at the upper end on these soils (Chiple and Hurricane). Fertilization using DAP+urea, the one-time layer litter, and the annual layer litter applications did not improve slash pine growth and yield.

Recommendations

Forest landowners should continue to use established fertilization diagnostic tools: (1) leaf area index (LAI) estimates, (2) soil sampling for available P, and (3) foliar sampling as well as soil series and land use history knowledge for cost-effective fertilization prescriptions. Fertilization, in this case, was not cost-effective over the 4-year period and lead to increased tree mortality and lower yields in conjunction with high winds and wet soils in 2004. For more information on the diagnostic tool use and results interpretations go to the *Fertilization* heading on these web sites: www.bugwood.org and www.forestproductivity.net.

Table 1. Application amounts, dates, and macro- and micro-nutrient levels for the fertilizer treatments used in the unthinned old-field 1994 planted slash pine stand in Brantley County, Georgia

Fertilizer treatment	Application date(s)	Amount	Total-N	P ₂ O ₅	K ₂ O	B	Cu	Zn
				(lbs/ac)				
Control		0	0	0	0	0	0	0
DAP+urea (NP)	Jan 2002	250+335	200	115	--	--	--	--
†One-time litter	Jan 2002	25,500	275	610	370	0.41	0.32	2.9
†Annual litter	Jan 2002	6,920	95	165	100	0.11	0.08	0.80
	Feb 2003	7,160	180	340	210	0.26	0.55	2.7
	Feb 2004	7,480	115	255	110	0.17	0.31	2.4

†Mean layer litter N concentrations (on an as sampled basis) are as follows: One-time litter; total-N 1.08%, HN₄-N 0.66%, and organic-N 0.42%. Annual litter; Total-N 1.80%, HN₄-N 0.42%, and organic-N 1.38%. Nitrate-N in the layer poultry litter was negligible ranging from 0.010 to 0.034 ppm. Litter solids averaged 30% (20-40% range).

Table 2. Surface soil (0-6) pH, available (Mehlich I) nutrients and total nitrogen in the unthinned old-field 1994 planted slash pine stand in Brantley County, Georgia (Hurricane and Chipley soils).

Date	Treatment	pH	P	K	Ca	Mg	Mn	B	Cu	Zn	Total-N
-----lbs per acre-----											percent
Oct2001	Control	5.5	184.55	29.39	428	24.1	3.6	0.09	0.37	1.55	0.037
	NP	5.3	143.88	24.46	379	22.8	3.3	0.16	0.37	1.46	0.047
	One-time litter	5.6	202.62	25.41	526	29.3	3.8	0.10	0.33	1.40	0.042
	Annual litter	5.6	205.83	27.70	489	26.4	2.5	0.10	0.33	1.30	0.038
Feb2003	Control	5.5	163.57	32.97	350	16.5	2.5	0.14 c		1.11	0.029
	NP	5.2	150.83	32.55	294	14.3	2.0	0.16 bc		1.21	0.211
	One-time litter	5.9	211.50	59.05	518	31.0	3.4	0.21 a		1.40	0.033
	Annual litter	6.0	230.20	53.66	546	25.6	2.3	0.21 ab		1.49	0.037
Feb2004	Control	5.1 b	183.53 b	29.60 c	382 b	18.5 b	4.1			1.73 b	
	NP	5.0 b	177.13 b	28.94 c	350 b	18.8 b	3.7			1.71 b	
	One-time litter	5.7 a	287.83 a	54.65 b	837 a	52.9 a	5.4			2.75 b	
	Annual litter	5.7 a	360.67 a	68.62 a	1068 a	64.6 a	5.0			4.15 a	
Feb2005	Control	5.1 b	147.80 b	22.78 b	379 c	16.7 c	4.0 b			2.90 b	
	NP	4.8 b	136.47 b	21.78 b	328 c	19.9 c	4.3 b			3.15 b	
	One-time litter	6.0 a	315.10 a	49.95 a	1231 b	58.6 b	5.3 b			6.17 a	
	Annual litter	5.9 a	379.40 a	65.22 a	1432 a	76.1 a	8.2 a			6.84 a	

Means followed by a different letter are significantly different within a measurement year for the growth parameters tested above using Duncan's Multiple Range Procedure at the 5% alpha level.

Table 3. Foliar nutrient status in the unthinned old-field 1994 planted slash pine stand in Brantley County, Georgia (Hurricane and Chipley soils).

Date	Treatment	N	P	K	Ca	Mg	Mn	B	Cu	Zn				
		-----percent-----					-----parts per million-----							
Nov2001	Control	1.06	0.15	0.63	0.23	0.10	55.0	6.44	2.93	30.49				
	NP	1.13	0.13	0.42	0.31	0.08	50.0	7.97	1.73	28.64				
	One-time litter	1.10	0.14	0.44	0.27	0.09	67.1	8.02	1.94	31.30				
	Annual litter	1.16	0.15	0.52	0.31	0.09	56.1	6.89	2.56	33.19				
Feb2004	Control	1.24	0.12	0.44	0.25	0.08	60.1	6.66	2.59	ab	40.07	a		
	NP	1.29	0.10	0.37	0.29	0.09	63.2	7.44	2.98	a	34.18	b		
	One-time litter	1.45	0.10	0.46	0.25	0.07	24.3	8.50	2.25	b	29.01	c		
	Annual litter	1.42	0.09	0.38	0.17	0.05	18.5	10.37	1.77	c	23.97	d		
Feb2005	Control	1.17	0.11	0.39	b	0.26	0.09	72.7	a	5.42	b	1.27	39.69	a
	NP	1.41	0.13	0.42	b	0.29	0.09	66.8	a	5.79	b	2.50	42.92	a
	One-time litter	1.25	0.11	0.42	b	0.27	0.10	43.8	ab	8.09	b	2.16	42.12	a
	Annual litter	1.39	0.11	0.54	a	0.20	0.11	20.2	b	13.45	a	0.84	22.97	b

Means followed by a different letter are significantly different within a measurement year for the growth parameters tested above using Duncan's Multiple Range Procedure at the 5% alpha level.

Table 4. Mean trees per acre, dbh, height, and volume/tree by treatment in the unthinned old-field 1994 planted slash pine stand in Brantley County, Georgia (Hurricane and Chipley soils).

Month Year	Fertilizer Treatment	Trees/ acre	Dbh (in)	Basal area (ft ² /ac)	Total height (ft)	Volume /tree (ft ³)	Volume /ac (ft ³)
Jan2002	Control	673	4.7	82	23.8	1.64	1107
	NP	663	4.7	82	24.4	1.71	1130
	One-time litter	640	4.7	73	24.4	1.72	1096
	Annual litter	677	4.6	81	23.6	1.61	1089
Jan2004	Control	660	5.6	118	32.4	3.04	2015
	NP	630	5.8	119	33.5	3.35	2095
	One-time litter	607	5.9	118	31.8	3.29	1996
	Annual litter	647	5.7	118	32.4	3.13	2024
Jan2006	Control	657	6.3	146	40.6	4.53	2985
	NP	573	6.5	136	41.8	4.97	2815
	One-time litter	560	6.7	141	40.7	5.12	2865
	Annual litter	570	6.5	135	40.9	4.87	2765

There were no statistically significant differences between treatment means within a measurement year for the parameters listed above using Duncan's Multiple Range Procedure at the 5% alpha level.

Table 5. Growth increment between measurement periods for dbh, basal area, height, and volume/tree by treatment in the unthinned old-field 1994 planted slash pine stand in Brantley County, Georgia (Hurricane and Chipley soils).

Period	Treatment	% mortality	Dbh (in)	BA/ac (ft ²)	Total height (ft)	Volume/ tree (ft ³)	Volume/ acre (ft ³)
2002-2004	Control	1.9	0.97 b	35.7	8.6	1.40	908
	NP	5.0	1.13 a	37.3	9.1	1.64	965
	One-time litter	5.2	1.18 a	44.8	7.4	1.58	900
	Annual litter	4.4	1.07ab	36.8	8.7	1.52	934
2004-2006	Control	0.5	0.65	28.3	8.3	1.48	970
	NP	9.0	0.70	16.3	8.3	1.62	720
	One-time litter	7.7	0.83	23.1	8.9	1.83	870
	Annual litter	11.9	0.81	17.1	8.6	1.73	742
2002-2006	Control	2.4	1.62	64.0	16.8	2.89	1878
	NP	13.6	1.83	53.6	17.4	3.26	1685
	One-time litter	12.5	2.02	67.9	16.3	3.41	1770
	Annual litter	15.8	1.88	53.9	17.3	3.25	1676

Means followed by a different letter are significantly different within a measurement year for the growth parameters tested above using Duncan's Multiple Range Procedure at the 5% alpha level.

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