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Poultry Litter Application Recommendations in Pine Plantations

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INTRODUCTION

Forest fertilization in the southeastern U.S. has increased from the 1960s to the late 1990s. In 1999, an estimated 1.58 million acres were fertilized while by 2016 an estimated 589,000 acres of loblolly and slash pine stands were fertilized (Albaugh and others 2019). Common fertilizers used are diammonium phosphate (DAP; 18-46-0), urea (46-0-0), or triple super phosphate (TSP; 0-46-0) although TSP has become harder to procure in the last 10 years. Loblolly pine is considered to be the southern pine species which is most responsive to fertilization and other cultural practices. Slash, longleaf pine, and other southern pine stands are also fertilized but not to the extent that loblolly pine plantations are fertilized. Rates of return from fertilization typically average 8-12%, but can be as high as 20% depending on fertilizer and application costs, extra wood grown, wood product class values and other forest product (i.e. pine straw) yield increases. Optimal use of any fertilizer material requires that some diagnostic tools are used along with soils and land used history knowledge. These diagnostic tools include soil and foliage analysis, leaf area index (LAI) estimation, soil classification/grouping, visual symptoms, growth and yield modeling, and stand fertilizer trials (Jokela et al. 1991, Dickens 1999).

Generally there are three fertilization recommendation "windows" in pine plantations:

1. **at planting** or **early post-planting** to correct a nutrient deficiency (largely P limitations or specific micronutrients such as boron or copper),
2. **at canopy closure, age 5-12 years-old** (usually N+P), and
3. **after a 1st or 2nd thinning** in semi-mature stands (N, P, sometimes K, and micronutrients) or several years following thinning in semi-mature stands (N, P, sometimes K, and micronutrients).

Site-specific conditions determine the type and rate of fertilization within each of the above windows. For example, to correct a nutrient deficiency such as P in poorly to very poorly drained Atlantic Coast Flatwoods soils, a single application of phosphorus such as TSP @ 125-250 lbs/acre is often applied at planting (Jokela et al. 1991). In another case, nitrogen (N) plus phosphorus (P) such as DAP @ 125-250 lbs/acre is the general choice at planting if competing vegetation is controlled by herbicide application; however, this N+P DAP fertilization is not recommended if competing vegetation is not controlled. In the latter case, competing vegetation should be controlled pre- and post-planting during which the nutrient demands of pine seedlings/saplings are relatively low. In older loblolly and slash pine plantations that have reached canopy closure (after five- to twelve-years-old) or after a thinning, diammonium phosphate and urea (@ 125-200 lbs DAP and 300-385 lbs urea/acre) are commonly applied in loblolly and slash pine stands.

Fertilization to enhance pine straw production in unthinned and thinned stands on low fertility cutover sites is often recommended when raking occurs annually or more frequently then two to three times in the life of a stand (N, P, sometimes K, Mg, S, and micronutrients). Pine plantations should be fertilized every four to eight years to replace the nutrients removed when the straw (fresh brown needles or the forest floor litter layer) is raked and taken from the site.

BENEFITS OF POULTRY LITTER APPLICATION TO FOREST LAND

The non-industrial private forest landowner (NIPFL) sector has become increasingly interested in using commercial and other fertilizer materials such as poultry litter to fertilize stands. Approximately two-thirds of South Carolina and Georgia are forested, two-thirds of the forest land in these two states are owned by non-industrial private forest landowners. Both states are large poultry producers.

There are several advantages to forest land application of poultry litter.

1. **An abundance of forest land to apply poultry litter**
2. **A year-around window to apply poultry litter**
3. **Forest soils on cutover sites are generally low in plant available phosphorus (P).**
4. **Pine stand wood volume and straw production response to a single application of poultry litter can be significant and relatively long lived (four to ten years)**
5. **The addition of macro-nutrients other than N and P and micro-nutrients (especially Cu and Zn)**
6. **Adding organic matter to the site (tons/acre)**
7. **Increasing soil moisture holding capacity.**

Limitations of Poultry Litter Application to Forest Land
There are some limitations to the use of poultry litter to fertilize forest lands.

8. **Access,** row spacing, turning radius, stump height, and rutting depth
1. **Excessive slope** (>8 percent)
2. **Application levels to achieve nitrogen per acre goals are typically in tons/acre.**
3. **Hauling distance** (Bush *et al.* 1999)
4. **Labor and time constraints**
5. **Spreader availability**

Forest landowners and poultry producers need to check all aspects of application to make sure forest land application of poultry litter is feasible. Table 1 provides a checklist for landowner, stand, litter, and equipment needs.

Table 1. A Checklist for Pine Plantation Poultry Litter Application

Factor	Check	Satisfied/ Unsatisfied
Interested landowners	Distance to sensitive areas acceptable (churches, neighborhoods, water bodies, etc.)	
Suitable stand(s):	Access (row thinned, >10 to 12' between row if unthinned), turn-around areas	
	Percent slope <8%	
	% hardwoods (<10% of stand basal area)	
	% fusiform rust stem canker incidence (<25% for slash and <30% for loblolly)	
Litter availability	Amount (tons) and distance (miles) from stands	
Equipment availability	Old-field sites: spreader, tractor (minimum HP is 50 to 75), cut-over sites: skidder + spreader box, at house: front end loader	
N or P per acre stand needs	Species, age, stocking, soils (refer to Table 2)	
Tons per acre application level	Based on Table 2 and examples following	
Calibration area	Near litter source; open fields	

If any of the above criteria are not satisfied then other options/sites may need to be pursued.

WORKSHEET FOR DETERMINING THE RECOMMENDED APPLICATION LEVELS OF POULTRY LITTER

Fill in the following information about stand characteristics and nutrient needs:

Species: __________

Age: __________

% Hardwood basal area __________

(if > 10% of stand basal area then control hardwoods first if optimizing pine production is a primary goal)

% Fusiform rust stem canker incidence __________

(if >25% for slash or 30% for loblolly then split apply litter or delay application until after thinning)

P needs = pre- to early post-planting (Table 2) __________

N needs = canopy closure, pine straw prodn, after thinning (Table 2) __________

<u>A. At planting to early post-planting tons/acre calculation based on P needs:</u>

Assume stand needs 50 lbs elemental-P/acre (114 lbs P_2O_5). Using Table 3 as the litter analysis example, assume 1.24% elemental-P/ton (2.83% P_2O_5) "as sampled" in the litter or 0.0124 fraction of litter is elemental-P.

Step 1: determine target N or P needs/acre

Goal = 50 lbs elemental-P/acre for at planting (114 lbs P_2O_5)

Step 2: determine target nutrient (in this case P) lbs/ton in litter

In litter = 2000 lbs x 0.0124 = 24.8 lbs elemental-P per ton litter (56.5 lbs P_2O_5/ton)

Step 3: divide target P needs/acre (lbs/acre) by elemental-P in litter (lbs P/ton litter)

50 lbs P/acre ÷ 24.8 lbs P/ton litter approximately 2 tons/acre (as P_2O_5 114 56.5 = 2 tons/ac)

Actual Analysis Values:	_____x_____	percent elemental-P (or P_2O_5) in litter ÷ 100
	_____y_____	lbs elemental-P/ton (or P_2O_5) litter = 2000 * x
	_____50____	Target elemental-P application level
or	____114____	Target P_2O_5 application level

Calculation for tons/acre of litter = 50 ÷ y = tons/acre based on elemental-P needs

or Calculation for tons/acre of litter = 114 ÷ y = tons/acre based on P_2O_5 needs.

Generally at **planting tons/acre for most broiler, breeder, and layer litters based on P needs = 1 to 2 tons/acre.

B. At canopy closure or after thinning tons/acre calculation based on total-N calculation:

Assume loblolly or slash pine stand needs 200 lbs total-N/acre. Using Table 3 as the litter analysis example; total-N is 2.7%

Step 1: determine target N or P needs/acre

Goal = 200 lbs total-N/acre for application at canopy closure or after thinning

Step 2: determine target nutrient (in this case total-N) lbs/ton in litter

In litter = 2000 lbs x 0.0270 = 54.0 lbs N per ton litter

Step 3: divide target N needs/acre (lbs/acre) by total-N in litter (lbs total-N/ton litter)

200 lbs N/acre 54 lbs N/ton litter = 3.7 tons/acre

Actual Values:	_____x_____	percent total-N in litter 100
	_____y_____	lbs total-N/ton litter = 2000 * x
	_____200___	Target total-N application level

Calculation for tons/acre of litter = 200 y = tons/acre based on total-N calculation. The 3.7 tons/acre poultry litter application level would also have 92 lbs total-P (210 lbs P_2O_5), 138 lbs total-K (166 lbs K_2O), 144 lbs Ca, 0.28 lbs B, 2 lbs Cu,& 2 lbs Zn/ac.

Generally **canopy closure or after thinning application levels based on total-N using most broiler, breeder, and layer litters are:

1. in **loblolly and slash pine stands** = 3 to 5 tons/acre
2. in **longleaf stands** (dbh dependant) = 1 to 2.5 tons/acre

C. At canopy closure or after thinning tons/acre calculation based on plant available-N (PAN)calculation:

Assume landowner would like to apply 200 lbs PAN/acre in a loblolly or slash pine stand. Using Table 3 as the litter analysis example; PAN = 50% of organic-N + 60% of NH_4-N + 100% of NO_3-N or 60% of total-N in the first year.

We will assume 60% of total-N is plant available-N (PAN) as an estimate in this case.

Step 1: determine target N or P needs/acre
Goal = 200 lbs PAN/acre for application at canopy closure or after thinning

Step 2: determine target nutrient (in this case PAN) lbs/ton in litter
In litter = 2000 lbs/ton x (0.0270 x0.60) = 32.4 lbs PAN per ton litter

Step 3: divide target N needs/acre (lbs/acre) by PAN lbs/ton estimate in litter
200 lbs PAN/acre 32.4 lbs PAN/ton litter estimate 6.2 tons/acre

Actual Values: _____x_____ percent total-N in litter 100 * 0.60
_____y_____ estimated lbs PAN/ton litter = 2000 * x
_____200___ Target PAN application level

Calculation for tons/acre of litter = 200 y = tons/acre based on PAN calculation.

Generally **canopy closure or after thinning application levels based on PAN using most broiler, breeder, and layer litters are:

1. in **loblolly and slash pine stands** = 5 to 7.5 tons/acre
2. in **longleaf stands** (dbh dependant) = 2 to 3.5 tons/acre

APPLICATION LEVELS IN SOUTHERN PINE PLANTATIONS

Loblolly pine is the most nutrient demanding of our Atlantic and Gulf Coastal Plain southern pines, slash pine is intermediate in nutrient demands, and longleaf is the least nutrient demanding. The poultry litter application level should be specifically designed to meet landowner objectives, and species, age, stocking, and site specifications. For example, too much nitrogen can make young longleaf pines top-heavy due to too much foliage produced in a short period of time. The stem cannot support the extra weight and 15-20% of a stand can lean over and never recover (Dickens 2000).

Nitrogen and P recommendations in Table 2 are derived from a combination of numerous commercial fertilizer poultry litter trials in loblolly, longleaf, and slash pine plantations and are currently "best estimates". The values in the table are a compromise between environmental issues and silvicultural production optimums. Several poultry litter application projects are underway or are being proposed in the southeastern U.S. As information is collected and summarized, the N and P application recommendations will be refined. Before beginning a fertilization program, it is advisable to check with the Cooperative Extension Service and/or the State Forestry Commission for the current N and P recommendations particular to the state and pine stand factors. Excellent weed control must be achieved prior to applying poultry litter in young stands that have not reached canopy closure. Initial poultry litter applications in pine plantations will typically be based on P (at planting) or N needs (after canopy closure). Annual poultry litter applications in pine plantations is usually unrealistic and economically not feasible due to the higher demand for the nutrient rich litter.

Tons per acre rate determination may be based on total-N (organic-N + ammonium/ammonia-N + nitrate/nitrite-N) or PAN (plant available N) in the poultry litter. Total-N is much easier to quantify analytically but not all of total-N may be plant available in the first or second growing season. Total Kjeldahl N (TKN) is a good estimate of total-N where nitrate/nitrite-N is negligible.

A second, frequently used basis for determining the N rate for crop and pastureland is plant available-N or PAN. Generally 100% of nitrate/nitrite-N, 50 to 60% of ammonium/ammonia-N (when surface applied), and 40 to 50% of organic-N (total Kjeldahl-N minus ammonium-N) are estimated to be plant available in the first growing season. Ammonium can be converted to nitrate or transformed to ammonia. Ammonia is a gas that can be readily lost to the atmosphere. Ammonia losses are dependent on temperature, moisture, relative humidity, wind speed, and micro-environment pH. If a 1/4 inch or more rain occurs within 24 hours of surface applied poultry litter application, ammonia-N losses can be minimal. Often PAN in most poultry litters is estimated to be 50% to 60% of total-N when surface applied. Poultry litter incorporation with disking should be done within 24 to 48 hours of application to minimize N losses. Disking to incorporate litter is limited to intensively prepared cut-over, old field, and pasture sites months prior to planting and is not recommended in established pine stands.

Table 2. Nitrogen (N) and phosphorus (P) fertilization recommendations for single or repeat applications every 5 or more years to southern pine species in well stocked stands (broadcast and surface applied).

Species	Age(yrs)/Size	N Recommendation	P Recommendation
		-lbs/acre-	
Loblolly[1]	1 to 4	40 to 50	25 to 50
	5 to 10	80 to 150	20 to 50
	11 to 35	200	25 to 50
Slash[2]	1 to 4	40 to 50	25 to 50
	5 to 10	70 to 110	25 to 50
	11 to 35	150 to 200	25 to 50
Longleaf	Establishment	not recommended	
	mean dbh < 6.0"	50 to 75	25 to 50
	mean dbh >= 6.0"	100 to 125	25 to 50

[1] fusiform stem canker incidence < 30% and hardwood basal area/acre < 10 ft2
[2] fusiform stem canker incidence < 25% and hardwood basal area/acre < 10 ft2
Excellent woody and herbaceous weed control is needed when applying at age 1 to 4 yrs old

Table 3 lists the average nutrient content of unprocessed broiler litter that was analyzed by the University of Georgia's Agricultural and Environmental Services Laboratory during 1994-97.These results were used in examples A, B, and C to estimate the tons/acre of broiler litter needed to achieve 50 lbs elemental-P/acre, 200 lbs total-N/acre, or 200 lbs PAN/acre, respectively, in loblolly and slash pine stands. Table 4 lists mean nutrient concentrations for samples received in 2000-2001 at the UGA Agricultural and Environmental Services laboratory. Tables 5a, 5b, and 5c are the nutrient values from the UGA laboratory for breeder, layer and broiler litter in 2021.

Fertilization with poultry litter to enhance pine straw production can be made every four to eight years. The N and P fertilizer recommendations listed in Table 2 should be used to determine the poultry litter application tons/acre needs. Fertilization using poultry litter, other organic fertilizer materials, and commercial fertilizers will generally increase pine straw production by 40-50% starting 15 to 24 months after application and last 3 to 5 years (Dickens 2000). Wood volume should also increase, generally by 15 to 40% during this same period (Dickens and Miller 1998, Dickens 2000, Dickens et al. 2002c). refer to *Pine straw raking and growth of Southern Pine: Review and recommendations* (Dickens et al. 2020) on bugwood.org for more specific fertilization recommendations for pine straw production.

Table 3. Unprocessed broiler litter nutrient content analyzed by UGA Agricultural and Environmental Services Labs 1994-1997 (463 samples). Results reported on an " as sampled" basis.

Nutrient	Concentration (%)	lbs/ton (as sampled)
total-N	2.70	54
organic-N	1.50	30
NH_4-N	1.18	23.6
NO_3-N	0.02	0.4
total-P	1.24	24.8
total-K	1.86	37.2
total-Ca	1.94	38.8
B	0.00378	0.076
Cu	0.0266	0.53
Zn	0.0287	0.57

PRECAUTIONS

Special care should be taken in a pine stand in loblolly, longleaf, and slash pine's northern range where ice and snow are common and can weigh down crowns or where stem fusiform rust cankers are relatively high (> 25-30%). A forest landowner does not want to loose 15-20% of their stand due to producing top-heavy trees that lean over and never recover. This has happened in more than one case in young longleaf stands with over application of N from organic and inorganic fertilizers (Dickens 2000). Fertilization using poultry litter is not recommended in areas of high risk of pitch canker and annosum root rot.

For forest land application of poultry litter, the recommended water table depth at time of application should be greater than 20 inches for sandy soils and 30 inches for loamy to clayey soils. Crop tree growth can be reduced by damage to perennial tree root systems and by soil compaction when applications are made during higher water table periods. Soil compaction may also produce an anaerobic soil condition that can increase ammonium-N levels and reduce seedling survival. Heavy equipment should not be used to apply poultry litter at a site where water can be squeezed out of a handful of soil.

Table 4. Results of poultry litter analysis at UGA Agricultural and Environmental Services Laboratory. In the absence of site specific data, these values provide a good basis for nutrient management planning. Values are in percent followed by one standard deviation( ). All values are on an "as received" basis (not dry weight basis).

Nutrient	Fresh Broiler Litter	Stockpiled Broiler Litter	Composted Broiler Litter	Fresh Layer Litter	Fresh Broiler Breeder Litter
Nitrogen (N)	3.15%(0.60)	2.78%(0.86)	2.80%(0.98)	2.26%(0.83)	2.12%(0.79)
Phosphate (P_2O_5)	2.77 (0.81)	2.84 (0.94)	3.00 (1.00)	3.16 (1.34)	3.14 (1.17)
Potassium (K_2O)	2.33 (0.62)	2.29 (0.69)	2.30 (0.83)	2.05 (0.81)	1.93 (0.63)
Calcium (Ca)	1.80 (0.84)	1.92 (0.96)	2.05 (1.21)	6.43 (3.38)	6.38 (2.71)
Magnesium (Mg)	0.39 (0.12)	0.40 (0.12)	0.40 (0.24)	0.37 (0.15)	0.35 (0.14)
Sulfur (S)	0.42 (0.16)	0.39 (0.13)	0.40 (0.15)	0.36 (0.15)	0.38 (0.18)
Boron (B)	0.003 (0.003)	0.003 (0.001)	0.003 (0.001)	0.021 (0.001)	0.002 (0.001)
Copper (Cu)	0.034 (0.018)	0.033 (0.019)	0.029 (0.016)	0.011 (0.013)	0.011 (0.017)
Zinc (Zn)	0.027 (0.008)	0.028 (0.010)	0.026 (0.008)	0.029 (0.014)	0.028 (0.010)
# of Samples	3113	309	85	180	418

From: D. Kissel, Annual Poultry Litter Test Summary July 2000- July 2002, UGA Agricultural and Environmental Services Laboratory, 2400 College Station Road, Athens, GA 30602.

Table 5a. University of Georgia 2021 data for fresh or stockpiled Breeder Litter from the UGA Soil, Plant, and Water Laboratory Poultry Litter Test Summary

		Parts per million (ppm)												
Samples	**Stats**	**N**	**P_2O_5**	**K_2O**	**Ca**	**Mg**	**S**	**Mn**	**Fe**	**Al**	**B**	**Cu**	**Zn**	**Na**
Litter-Breeder-Fresh														
25	Mean	19627	33780	24281	68427	4143	4980	327	1372	1903	185	298	329	5004
	Min	8690	11381	8953	11646	1304	2087	124	413	149	18	39	103	1808
	Max	35240	59082	35125	127457	7790	9520	592	9767	19750	681	427	667	7986
	Stdev	6501	13446	6035	34840	1659	1964	113	2135	4677	168	106	138	1560
Litter-Breeder-Stockpiled Stackhouse														
3	Mean	14620	21124	12043	59000	4901	3762	315	1668	1675	17	167	281	2687
	Min	9780	12114	687	33540	3323	1307	192	684	532	5	137	172	197
	Max	23680	38838	31339	108700	7650	8280	540	3474	3866	35	196	497	7058
	Stdev	7852	15342	16798	43046	2389	3917	195	1566	1898	16	29	187	3798

Table 5b. University of Georgia 2021 data for fresh or stockpiled layer litter from the UGA Soil, Plant, and Water Laboratory Poultry Litter Test Summary

		Parts per million (ppm)												
Samples	**Stats**	**N**	**P_2O_5**	**K_2O**	**Ca**	**Mg**	**S**	**Mn**	**Fe**	**Al**	**B**	**Cu**	**Zn**	**Na**
Litter-Layer-Fresh														
8	Mean	23745	25563	21585	63398	4033	6393	267	1156	1262	24	179	273	3548
	Min	14920	15517	11224	19862	2076	1338	176	446	274	19	24	200	1636
	Max	38000	36182	28174	92505	5583	24345	331	4041	5743	36	389	364	5273
	Stdev	7943	7926	5559	22118	1340	7361	60	1200	1847	6	156	67	1448
Litter-Layer-Stockpiled Stackhouse														
9	Mean	29400	29304	21068	80430	5665	4680	292	888	963	21	42	312	2300
	Min	22210	20376	13268	63282	4131	3476	159	544	468	12	26	202	1324
	Max	35860	50877	34457	130862	10263	7794	457	2072	3627	33	52	434	3819
	Stdev	4626	9926	6148	22035	1843	1418	98	464	1010	7	9	69	719

Table 5c. University of Georgia 2021 data for fresh, stockpiled, or composted broiler litter from the UGA Soil, Plant, and Water Laboratory Poultry Litter Test Summary

		Parts per million (ppm)												
Samples	Stats	N	P_2O_5	K_2O	Ca	Mg	S	Mn	Fe	Al	B	Cu	Zn	Na
Litter-Broiler-Fresh														
90	Mean	29887	28595	36367	24810	6247	11266	408	2139	4312	70	341	369	7152
	Min	7230	5519	7600	4106	1357	1073	120	267	181	7	14	52	1299
	Max	39440	50268	48706	133337	10870	21910	813	15066	20114	965	743	576	18590
	Stdev	4793	7667	6569	20489	1372	4267	134	2279	3964	115	163	96	2836
Litter-Broiler-Stockpiled Stackhouse														
37	Mean	28818	28923	35885	29227	6172	9374	435	2996	3689	59	305	416	6441
	Min	10320	12656	12935	12450	2340	2214	159	438	153	13	24	184	1803
	Max	37800	58017	60442	151942	9725	20060	745	13078	11497	227	724	678	9445
	Stdev	6497	9473	10347	23403	1964	3860	148	3159	3163	39	184	121	1880
Litter-Broiler-Composted														
6	Mean	28233	27689	33298	22943	6140	9325	435	1291	2878	43	260	420	5711
	Min	11220	15533	8564	14855	4006	3365	262	744	789	20	177	213	774
	Max	33870	32578	43029	28316	7191	11217	583	2336	4282	58	452	624	7763
	Stdev	8544	6124	13312	6193	1138	2978	126	591	1295	17	106	137	2486

PRELIMINARY RESEARCH FINDINGS

At Planting

Bush *et al.* (1998) studied loblolly pine survival after two growing seasons in the lower Coastal Plain of Georgia on Bladen, Chipley, Albany, and Blanton soils. Weeds were controlled in all plots during the first year. Survival was 97% in the 125 lbs DAP/acre plots, 95% in the 1 ton broadcast pelletized (4.5% total-N, 4% P_2O_5, 3% K2O) poultry litter/acre plots, and 91% for the controls (herbicide only). In years one and two on the Chipley soil (Aquic Quartzipsamment), mean total height and groundline diameter of the trees in the poultry litter + herbicide plots were significantly greater than the mean total height and groundline diameter of DAP + herbicide treated trees and the controls (Table 6). The poultry litter + herbicide pine groundline diameter was significantly greater than the control in year one on the Blanton and Albany soils, both of which are loamy, Grossarenic Paleudults.

Table 6. Summary of loblolly pine regeneration studies at three sites representing four soil types. Pine growth responses were evaluated during the first and second winters following treatment. Treatments received first year weed control (Bush et al. 1998).

Site	Soil	Treatment	Year 1[a] ht (ft)	Year 2 ht (ft)	Year 1[1] gld (in)	Year 2 gld (in)
Bladen, GA	Bladen	Control	2.98a	–	0.76ab	–
		Poultry L[2]	3.03a	–	0.82a	–
		DAP[3]	2.94a	–	0.72b	–
Ludowici, GA	Chipley	Control	2.57b	5.29b	0.86b	1.68b
		Poultry L	2.99a	5.81a	0.94a	1.94a
		DAP	2.47b	5.24b	0.82b	1.68b
Oliver, GA	Albany	Control	3.26b	–	0.86b	–
		Poultry L	3.56a	–	0.99a	–
		DAP	3.08b	–	0.90b	–
Oliver, GA	Blanton	Control	2.96a	–	0.87b	–
		Poultry L	3.10a	–	0.96a	–
		DAP	3.08a	–	0.90ab	–

[a] Means within a column and soil followed by the same letter are not significantly different at the 5% alpha level using Duncan's Multiple Range Procedure.
[1] gld = groundline diameter, [2] Poultry L = poultry litter @ 1 ton/ac, [3] DAP @ 125 lbs/ac.

A similar "at planting" trial was performed in a slash pine stand in the upper Coastal Plain of Georgia on a Fuquay soil (loamy, Arenic Plinthic Kandiudults). Treatments were (1) poultry litter (4% total-N, 3% P_2O_5, 2% K_2O) at 1 and 2 tons/acre, (2) 125 lbs DAP/acre, and (3) untreated controls (Bush *et al.* 1999). Weeds were controlled in all plots during the first year. Root collar diameter and total heights of the pines treated with 1 and 2 tons poultry litter/acre + herbicide and the 125 lbs DAP/acre + herbicide were significantly greater than the controls after the first growing season. Height was also greater after the 2nd growing season.

Wilhoit *et al.* (1998) reported that poultry litter applications of 2-8 tons/acre at pine establishment, without weed control, decreased height one to two years after treatment. When the weeds were controlled, there was a significant growth response.

Dickens *et al.* (2002b) evaluated an at-planting spot application (4 ft^2/seedling application area) fertilization trial in Quitman County, Georgia. In that study, DAP @ 200 lbs/ac (4.6×10^{-3} lbs/ft^2) and broiler litter @ 1.5 tons/ac (6.9×10^{-2} lbs/ft^2) with or without herbicides were applied to an old-field planted loblolly stand. This site had a high residual fertilizer value in the surface soil. Two-year groundline diameter and height increment means in the herbicide only (H) and herbicide+broiler litter (HP) plots was significantly greater than control (C) and poultry litter (P) only and DAP only (DAP) plots (Table 7). The HP and H treatment means were not significantly different after two years for diameter and height growth. The herbicide+DAP (H+DAP) treatment mean was not significantly different than the HP treatment for 2-year diameter increment but was significantly less than the HP for 2-year height increment (7).

The at-planting results presented by Bush *et al.* (1998,1999), Wilhoit *et al.* (1998), and Dickens *et al.* (2002[b]) suggest that the combination of poultry litter plus herbicide application at planting do as well as or will outperform typical inorganic fertilization. Conversely, poultry litter or inorganic fertilizer application without herbicide use at planting, may be detrimental to stand survival and growth.

Table 7. Two year summary of an old-field planted loblolly pine study in Quitman County, Georgia on Orangeburg and Troup soils. Pine growth responses were evaluated during the first and second winters following treatment. (Dickens *et al.* 2002[b]).

Treatment	1 year ht[a] increment (in)	2 year ht increment (in)	1 year gld[1] increment (in)	2 year gld increment (in)
Control	5.4b	37.6c	0.19c	0.91c
Herbicide	6.6a	47.3a	0.31a	1.09a
Poultry[2]	4.2c	33.6d	0.14d	0.75d
DAP[3]	4.8bc	38.4c	0.18c	0.91c
Herb+Poultry	5.6ab	45.5a	0.27b	1.04ab
Herb+DAP	6.6a	42.2b	0.31a	1.01b

[a] Means within a column followed by the same letter are not significantly different at the 5% alpha level using Duncan's Multiple Range Procedure.
[1] gld = groundline diameter, [2] Poultry = poultry litter @ 6.9 x 10-2 lbs ft^{-2}, [3] DAP @ 4.6×10^{-3} lbs ft^{-2}.

Mid-Rotation

Several studies have addressed the effects of poultry litter application in early to mid-rotation loblolly pine stands on growth response and water quality. Samuelson et al. (1999) found that two and four tons poultry litter/acre applied in an 18 year-old loblolly pine stand increased stem diameter growth after 18 months.

Dickens *et al.* (2002[c]) studied the effects of broiler litter applied at 7 tons/acre (450 lbs total-N, 240 lbs PAN, and 170 lbs elemental-P) versus DAP+Urea and no fertilizer treatment in an old-field, row thinned loblolly pine plantation (treatments applied at age 11 years-old within a year after thinning) on an eroded upper Coastal Plain Norfolk soil (fine-loamy, Typic Paleudults) in Clarendon County, South Carolina. They found that the broiler litter application increased 4-year diameter by 0.54 inch and height by 0.7 feet, respectively over the untreated controls and DAP+Urea (200 N + 50 P) plots (Table 8). Chip&saw (dbh > 8.5") volume in the poultry litter plots (13.5 cds/ac) was 5 cords/acre) greater than the unfertilized plots (8.5 cds/ac) (Figure 1) with a net gain of 4.5 cds/ac over the 4 year study period. The net extra chip&saw net growth (4.5 cds/ac) @ $65/cd four years after treatment for the poultry litter plots compared to the control (unfertilized) plot trees was $292.50/ac.

A METHOD TO REDUCE PATHOGENS IN POULTRY LITTER

Poultry litter (layer, breeder and broiler litter) can be piled outside each chicken house and turned a number of times increasing litter temperature to above 165 degrees F prior to applying the litter. This litter temperature increase will kill many of the common pathogens by piling, allowing the piles to increase in temperature, then turning the piles a number of times prior to transport and application.

EFFECT OF POULTRY LITTER APPLICATION ON WATER QUALITY

Beem *et al.* (1998) studied poultry litter applied at 0, 2, 4, 8, and 16 tons/acre and 500 lbs/acre of DAP+urea applied to a thinned loblolly pine stand (down to 110 TPA) in Oklahoma. Litter analysis indicated 60 lbs total-N, 50 lbs elemental-P, and 65 lbs K/ton. They monitored poultry litter and inorganic fertilizer effects on stream and shallow groundwater (soil water @ 1 and 2 feet) quality and stand growth response. They found that the soil water nitrate levels in the 8 and 16 tons/acre poultry litter plots were significantly higher than in the unfertilized plots. The 4 tons/acre and DAP+urea plots had significantly higher nitrate soil water concentrations than the unfertilized plots after one year (tenth storm event). Mean soil water nitrate-N concentrations met EPA drinking water standards (10 ppm) for all except the 16 tons/acre poultry litter plots. Mean nitrate-N concentrations were significantly higher downgradient of the study area (0.22 ppm) than upgradient of the study area (0.11 ppm) but met EPA drinking water standards. The DAP+urea, 4 and 16 tons/acre had 0.20" diameter growth increase over the unfertilized plots. All fertilizer treatments (inorganic and poultry litter) had greater height growth than the unfertilized plots ranging from an increase of 0.7' (4 tons/acre poultry litter) to 2.8' (8 tons/acre poultry litter).

Chastain *et al.* (2002) studied water quality effects of turkey litter applied to thinned 23-year-old loblolly on a Troup soil. They summarized that turkey litter applied at 120 lbs PAN/ac annually in May or November and 300 lbs PAN/ac applied one-time in May or November did not adversely effect groundwater quality with respect to nitrate-N values @ 16-22 feet in groundwater monitoring wells over a three year study. The maximum nitrate-N value was 1.76 mg/l (1.76 ppm) over the three year period.

Terauds-Stirrup *et al.* (2002) found that EPA drinking water standard was met for nitrate-N @ the 5 tons per acre of poultry litter application level but was not met @ the 15 tons per acre level in a loblolly pine plantation in Spaulding County, Georgia.

Table 8. Old-field, row-thinned loblolly pine mean dbh (diameter @ 4.5') and total height prior to and 4 growing seasons after poultry litter (7 tons/acre) and DAP+urea (250 lbs DAP+335 lbs urea/acre) application (900 TPA prior to thinning and 250 TPA after thinning) in the SC Coastal Plain (Norfolk soil).

Treatment	Dbh[a] (in)			Height (ft)		
	Year			Year		
	1998	2002	Increment	1998	2002	Increment
Control	6.16ab	7.98b	1.82	32.2b	41.3b	9.1
DAP+Urea	6.05b	7.94b	1.89	35.2a	43.3a	8.1
Broiler Litter	6.30a	8.73a	2.43	32.8b	42.6a	9.8

[a] Means within a column followed by the same letter are not significantly different at the 5% alpha level using Duncan's Multiple Range Procedure.

SUMMARY AND CONCLUSIONS

- When properly applied to pine plantations, poultry litter applications can increase tree growth, pine straw production, and revenue while cutting production costs and benefitting the environment.
- The principle limitation to litter application in pine stands is access. Other limiting factors include hauling distance, cost/ton, and number of acres applied/day.
- Poultry litter application rate/level determination depends on pine species, age, stocking, current site fertility, poultry litter characteristics, frequency of application, and soil test-P levels over time.
- Good weed control is required when poultry litter is applied pre- or early post-planting.
- In young longleaf pine stands (mean d.b.h. < 6") poultry litter application level should not exceed 75 lbs PAN/acre.
- Generally one-time or periodic (every 5 to 8 years) poultry litter application levels up to 5 to 8 tons per acre should meet EPA drinking water standard (<10 ppm) for nitrate-N.
- Pine stands where poultry litter is to be applied should have low (<25-30%) stem fusiform canker incidence and low hardwood stocking (<10 ft^2 BA/acre) to maximize the growth benefit to the crop pine trees (Dickens 2001).

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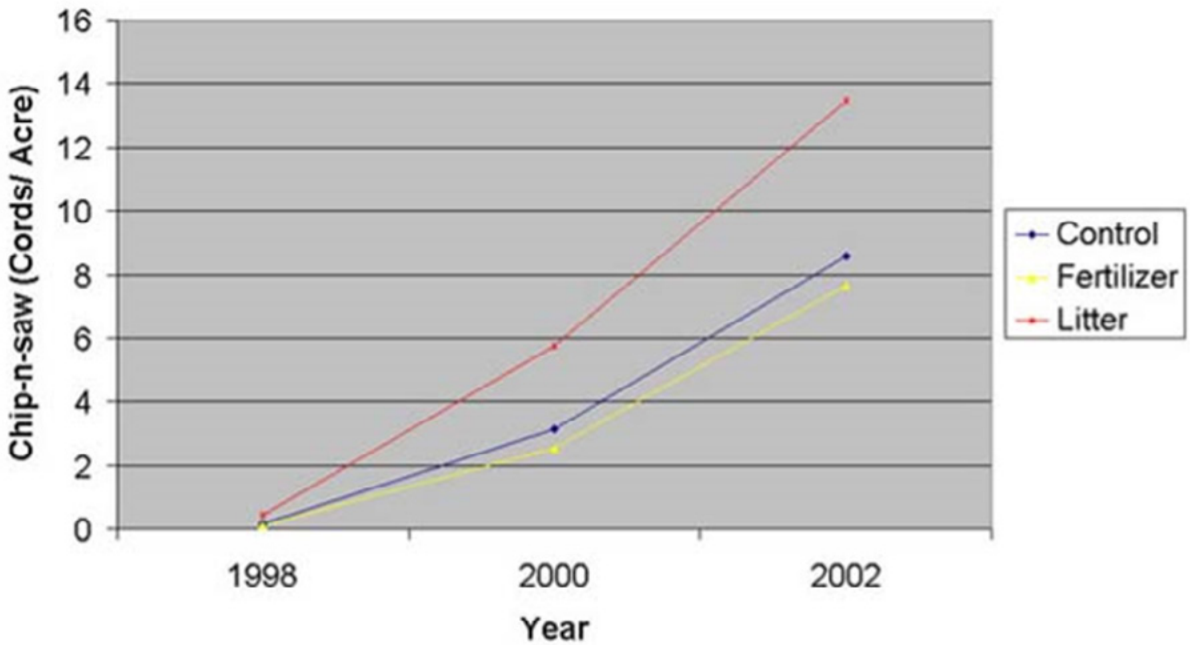

Figure 1: *Chip and saw (dbh >8.5") volume production 2 and 4 years after the first thinning (November 1997) by treatment (applied April/June 1998) in an old-field loblolly pine stand (Norfolk soil) in Clarendon County, South Carolina (1 cd/ac = 2.7 tons/ac stemwood+bark).*