G E O R G I A

Pine Plantation Fertilization

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Forest fertilization has increased greatly since the 1960s. Currently, there are an estimated 33.7 million (M) acres of loblolly pine, 10.4 M acres of slash pine, and 3 M acres of longleaf pine stands in the Southeastern U.S. (2001 figure). Approximately 1.3 M acres of loblolly and slash pine stands are fertilized in this region. Fertilization can increase loblolly, longleaf, and slash pine wood volume, pine straw production (used for mulch in landscaping), and per acre revenues. Fertilizer recommendations should be site-specifc and be based on soil type, land use history, control of competing vegetation, pine species, age, stocking (trees/A), and target products (pulpwood, sawtimber, poles, pine straw) to maximize fertilizer benefit.

Many acres of southern pines can potentially benefit from improved forest nutrition and result in sizeable investment returns. Proper fertilization should be considered an integral part of good forest management, and be based on the pine species grown, site and stand characteristics, target product goals, and market prices.

There are five common fertilizer types used in forest fertilization in the southeastern U.S. Common phosphorus (P) fertilizers include triple superphosphate (TSP, 0-46-0), and diammonium phosphate (DAP, 18-46-0). Common nitrogen (N) fertilizers include ammonium nitrate (34-0-0) and urea (46-0-0). Muriate of potash (MOP, 0-0-60) is used to add potassium (K) where needed. In some studies, the growth benefit with the addition of P and K can be two- to three-fold greater than that from N alone in loblolly, longleaf, and slash pine stands.

Fertilization of loblolly, longleaf, and slash pine stands can be economically attractive if the stand/site in question: 1) has a deficiency in one or more nutrients, 2) is responsive to the nutrient(s) being added, and 3) is large enough to be operationally managed (> 40 acres). Generally there are

TABLE 1. Critical ranges or values for soil and foliar nutrients in loblolly, longleaf, and slash pine.

		N	P	K	Ca	Mg	S	B	Cu
Surface soil, 0 to 6 in.	loblolly		<3-5[1]						
	longleaf		<4-6[2]						
	slash pine		<6-8[3]						
Foliage[4]	loblolly	1.2	0.12	0.35	0.12	0.07	0.12	4-8	2-3
	longleaf	0.9	0.08	0.30	0.10	0.06	0.10	4-8	1-3
	slash pine	1.0	0.09	0.30	0.10	0.05	0.10	4-8	1-3

[1]Expressed as parts per million (ppm) – (multiply ppm by 2 to approximate lb/A) – using Mehlich 1 or double acid extract procedures.
[2]Using Mehlich 2 procedure, ppm.
[3]Using Mehlich 3 or Bray P-2 procedures, ppm.
[4]N, P, K, Ca, Mg, and S expressed as %; B and Cu as ppm.

These two photos compare growth of 16-year-old loblolly pine on a Bladen soil (poorly drained) in Berkeley County, South Carolina. At left, management included herbicide, flat plant, but no P. At right, management was herbicide, flat plant, but with 185 lb P_2O_5/A.

three fertilization "windows": 1) at planting or early post-planting, 2) canopy closure (age 5 to 10 years) where crop trees occupy the site and nutrient demand can be greater than soil supply, or 3) after a thinning. Based on preliminary research, fertilization is also being recommended on a 3- to 5-year schedule after canopy closure to enhance pine straw production and maintain stand vigor.

There are an estimated 520,000 acres of mostly loblolly pine plantations that have been fertilized with P at planting, or early post-planting, using either DAP or TSP. Fertilizing at planting typically occurs on somewhat poorly to very poorly drained soils of the Lower Coastal Plain (Flatwoods). Somewhat poorly to very poorly drained (aquic) soils with an argillic (clayey) horizon in the southeastern Coastal Plain generally respond dramatically to P fertilization at planting. These sites are often deficient in plant-available P, especially as the percentage of clay increases (aluminum and iron in the clay will bind with P, making it less plant-available) and as soil drainage decreases.

Phosphorus fertilization with 115 lb P_2O_5/A, using TSP, can greatly increase pine growth. The response lasts 10 to 15 or more years on these sites. Some better-drained Upper Coastal Plain sites that have not been in cultivated crops in recent years can be P deficient. Soil and/or foliage tests can help verify any P deficiency (**Table 1**).

Phosphorus fertilization on these responsive, poorly to very poorly drained sites can be done either by ground or aerial application in conjunction with site preparation or planting. The current cost for P fertilization usually ranges between $40 and $50/A. This low cost along with a long-lived fertilizer response and dramatic volume gain make P fertilization of aquic soils in the southeastern Coastal Plain an attractive management option, especially if bedding (prior to planting) on these poorly drained soils was not performed or was not economically feasible for the landowner. Phosphorus fertilization at planting or early post-planting can mean the difference between having a stand and no stand as indicated in the photos (see above) with 16-year-old loblolly trees on a poorly drained, clayey Bladen soil in Berkeley County, South Carolina.

Often, somewhat poorly to very poorly drained soils of the Flatwoods are not recognized as P-deficient at planting. The resulting seedling growth is poor, needles are sparse and yellow-green to light green, especially in mid-winter. Loblolly pine on these sites often responds to P fertilization through at least the first 5 to 10 years after planting.

Fertilizer application of N plus P and in some cases K (based on needle tissue analysis), is recommended once a pine stand has

Growth response is shown in this wood disk from loblolly pine that was fertilized with NPK at the age of 26 years. Radial growth doubled four years after fertilization. (The split at left is not associated with fertilization.)

fully occupied the site and competing vegetation is sparse. This is one of the most common fertilizer application "windows" in forestry. Approximately 780,000 acres of well-established pine plantations (age 10 to 15 years old) were fertilized in 2001. At this stage in the life of a stand, nutrient demand is nearing its peak and the soil N and P supply can become growth limiting. Fertilizing loblolly, longleaf, and slash pine stands with NP or NPK, once canopy closure is reached or after a first or second thinning, will often increase growth for 5 to 8 years. The average growth response is a wood volume increase of 0.6, 0.5, and 0.4 cords/A per year for loblolly, slash, and longleaf, respectively. Fertilization 5 to 8 years before a first or second thinning or the final cut is recommended to capture the extra growth and to keep the stand from stagnating (when basal area gets above 150 ft^2/A). Knowing foliage N, P, K, calcium (Ca), magnesium (Mg), sulfur (S), boron (B), and copper (Cu) levels, soil extractable P levels, relative leaf area, and the soil series or drainage group will help in determining the probability of response to NP and other fertilization combinations. If pine growth is to be maximized on responsive sites, then repeat fertilization could occur every 4 to 5 years.

Pine plantations can stagnate on droughty, infertile, deep sands (Typic Psamments) such as Alaga, Alpin, Foxworth, Kershaw, Kureb, and Lakeland series found in the Sand Hills physiographic region of the Carolinas, Georgia, and Florida. Smaller doses of NPK fertilizer (100 lb N + 60 lb P_2O_5 + 90 lb K_2O/A every 2 to 3 years) can enhance growth and get the stand to merchantability. Longleaf pine and sand pine are better species choices on these sites.

Various diagnostic tools and techniques are used often in combination, to determine the magnitude, duration and potential economic benefit of fertilizing pine plantations. These diagnostic tools include experimental field trials, estimates of leaf area index, soil analysis, foliar analysis, soil surveys (mapping units), soil group and drainage class identification, and to a lesser extent presence of indicator plants, site index, and fertilization models.

Landowners can delineate the candidate stand(s) to be fertilized on an aerial photo of the property. The Natural Resources Conservation Service (NRCS) county map of the candidate stand can be used to determine the soil series and soils groups.

Pine stands of sufficient size for fertilization should be delineated on a soils map and on the ground into uniform areas of soil series or soil group, land use history (old-field, pasture, or cut-over sites), age, and stocking. Candidate stands for mid-rotation fertilization should meet the following criteria to capture the full benefits of fertilization: 1) stand stocking should be uniform and range from 400 to 900 trees/A in young stands or 60 to 90 ft^2 of basal area (BA/A, BA/A = the cross sectional area at 4.5 ft. above groundline of all trees) for stands 12 to 20 years old, 2) the hardwood component should be less than 10 to 15% of the total BA, 3) live crown length should be at least 15 to 20 ft. or preferably one-third of the tree height, 4) stands with 30% or more fusiform rust should be recognized as having a significant risk of excessive stem breakage from the added crown weight. High risk areas for pitch canker or root rot probably should not be fertilized, 5) any scheduled prescribed burning (to reduce hardwood competition and to lower wildfire risk) should be done either six months prior to or one to three years after fertilization, 6) over-stocked stands (BA/A

greater than 120 ft²) and/or stands with live crown ratios less than 30% should be thinned prior to fertilization. Thinning operations should leave the best trees. Thinning from below to remove poorly formed, suppressed, and intermediate trees will leave codominant and dominant trees that will respond best to fertilization. Pine stands that are 25 to 35 years old should respond to fertilization (see photo at left).

TABLE 2. Economics of extra wood grown from NPK fertilization of loblolly, longleaf, and slash pine stands after a first thinning (eight-year response period).

Species	Cost/A[1]	Extra cords/A Chip-n-saw[2]	Return/A[3]	IRR[4]
Loblolly	$106	4.8 cords	$360	16.5%
Longleaf	$72	3.2 cords	$240	16.2%
Slash	$89	4.0 cords	$300	16.4%

[1]Cost/A based on $0.06/lb application fee, DAP @ $200/ton, urea @ $215/ton, potash @ $160/ton (fall 2002 south Georgia prices). Loblolly @ 337 lb of urea, longleaf @ 120 lb of urea, and slash @ 228 lb of urea/A. All received 250 lb of DAP and 100 lb of MOP/A.
[2]Assumes a 0.40, 0.50, and 0.60 cord/A/yr response for longleaf, slash, and loblolly, respectively.
[3]Assumes a stumpage price of $75/cord for chip-n-saw (100% of extra wood grown).
[4]IRR = internal rate of return calculated as $[(\text{return/cost})^{1/8} - 1] \times 100$

Most pine plantation fertilization in the Southeast has been done on an as-needed, one-time, or periodic basis. A common planting or early post-planting P fertilization prescription is 100 to 140 lb of P_2O_5/A, using TSP on responsive Coastal Plain soils. Time of year is not critical with P fertilization of pine stands and application can be by ground equipment, helicopter, or fixed wing aircraft. A common NP fertilization mid-rotation prescription is 80 to 200 lb N/A plus 60 to 115 lb P_2O_5/A on responsive, better-drained soils of the Coastal Plain and Piedmont for loblolly pine. Loblolly pine N prescription is typically 200 lb N/A with P. Slash pine N prescription is typically 150 to 175 lb N/A with P and longleaf is 80 to 100 lb N/A with P. Urea is commonly the N source and researchers believe the best time to apply it is from November to early March to minimize N volitalization losses and to minimize new shoot growth burn when aerially applied. When foliar K is not sufficient, 50 to 90 lb K_2O/A as MOP should be applied along with N and P (**Table 1**). Calcium, Mg, and S fertilization in pine plantations is less frequent, but opportunities should not be overlooked when interpreting foliar analysis. Recently, B and Cu have been found to be insufficient for optimal growth (**Table 1**). Preliminary guidelines are to apply 1 lb of B/A and 3 lb of Cu/A when needle tissue analyses indicate deficiencies.

The economic attractiveness of pine plantation fertilization will vary due to several factors: 1) the extra quantity of wood grown and time frame, 2) the product class(es) grown (pulpwood, chip-n-saw, sawtimber, poles, and plywood logs), 3) extra pine straw grown (where of value and raked), 4) fertilizer amounts and fertilizer plus application costs, and 5) future stumpage prices for the extra wood grown. Generally, P fertilization pays at planting on P-deficient sites in the Flatwoods physiographic region due to low cost/A and the large, long-lived response. Fertilization with NP or NPK at canopy closure is relatively attractive if the growth response is large and pine straw income potential exists. Fertilization with NP or NPK after a thinning is attractive under recent timber prices, even though prices are depressed for chip-n-saw and sawtimber and very depressed for pulpwood. As shown in **Table 2**, internal rate of return (IRR) values in the 16% range are possible with proper fertilization. BC

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