Woodland Owner Notes

Nutrition Management for Longleaf Pinestraw

Introduction

Demand for pinestraw for use as mulch continues to rise dramatically. This demand has put considerable pressure on existing longleaf pine (*Pinus palustris*) stands due to frequent removal of pinestraw. While the sale of straw represents a financial opportunity for some private timberland owners, it can be a potential problem because of the repeated removal of nutrients from raked sites. Nutrient losses from a single removal of pinestraw are small and not likely to affect stand productivity. Research indicates, however, that frequent raking can result in significant nutrient losses. Nutrient-deficient stands produce less wood and foliage, and consequently less pinestraw, than stands with adequate nutrition. Commercial fertilizer can replenish nutrients as well as increase pinestraw production.

Pinestraw Production

Pine-needle-fall varies with stand density, site quality, nutrition, and weather conditions. Annual pinestraw production can be predicted using two of these factors: stand density and site quality. Stand density is described in terms of basal area: the total of the cross-sectional surface area of all stems, expressed in square feet per acre and calculated from tree diameters measured 4.5 feet above the ground. Site quality, or productivity, is expressed as site index: the height of dominant trees (in feet) at a standard age, such as 50 years. Estimates of the oven-dry weight of annual pinestraw production, as related to stand density and site index, have been developed from data on 29 plots in North and South Carolina (Table 1).

Table 1. *Predicted annual longleaf pinestraw production related to stand basal area and site index (in oven-dry pounds).*

	Site Index Base Age 50			
Basal Area	*60*	*70*	*80*	*90*
	Pinestraw Production (pounds per acre per year in oven-dry pounds)*			
80	*2,200*	*2,500*	*2,900*	*3,200*
100	*2,500*	*2,900*	*3,300*	*3,700*
120	*2,700*	*3,200*	*3,600*	*4,100*
140	*2,900*	*3,400*	*3,900*	*4,400*
160	*3,100*	*3,600*	*4,100*	*4,600*
180	*3,200*	*3,700*	*4,200*	*4,800*

*A fresh bale weighing 30 pounds, with 77 percent moisture content, would contain 25 oven-dry pounds of pinestraw.

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Nutrient Removals

Nutrients constantly cycle through the longleaf pine ecosystem. Once extracted from the soil by roots, they are transported to all parts of the tree, including the needles. Some nutrients, such as nitrogen (N), phosphorus (P) and potassium (K), are largely removed from the needles back into other parts of the tree through a process called *translocation* before needle-fall occurs (typically at the end of the needles' second growing season). Other nutrients, such as calcium (Ca) and magnesium (Mg), are less mobile within the tree and are not translocated.

Nutrients that remain in foliage when it falls from the tree are returned to the soil through decomposition by microorganisms and leaching by rainfall. The typical range of nutrient concentrations found in fresh pinestraw is presented in Table 2. Concentrations vary considerably from site to site.

Table 2. *Typical longleaf pine nutrient concentrations found in fresh pinestraw expressed as a percentage of oven-dry weight.*

	N	P	K	Ca	Mg
	Percent Concentration*				
Low	0.20	0.02	0.02	0.10	0.03
High	0.60	0.06	0.20	0.50	0.11

*Values are expressed as decimal fractions of 1 percent of sample dry weight.

The amount of nutrients returned to the forest floor through needle-fall each year depends on the concentration of nutrients in the fallen needles as well as the amount of needle-fall. Concentration of nutrients in the needles, in turn, depends on the original concentration in green foliage and the extent of translocation prior to needle-fall. The recommended procedure for determining pinestraw nutrient concentrations is to submit straw samples to a commercial plant tissue laboratory for analysis (see **Determining Nutrient Needs** in this publication).

To estimate the range of potential nutrient losses from pinestraw raking, multiply the nutrient concentration by the total dry weight of pinestraw removed (see Table 3). These estimates presume annual raking, with only one year's needle-fall removed by each raking. An unraked stand could have accumulated needles and organic material on the forest floor for many years. Because of decomposition, it is unlikely that collectable needles would exceed a three- to four-year accumulation.

In estimating nutrient removals, consider that harvesters often do not remove all of a stand's annual pinestraw production because of operational and practical constraints such as understory vegetation or closely spaced trees. Removals of pinestraw and nutrients should be adjusted by a factor representing the inaccessible amount of area or crop.

Table 3. *Estimated nutrient content in a single year's crop of longleaf pinestraw, in pounds per acre (combining Tables 1 and 2).*

Oven-dry Weight of Pinestraw (Pounds)	Nutrient				
	N	P	K	Ca	Mg
	Pounds per acre of element				
2,500	5-15	0.5-1.5	0.5-5.0	2.5-12.5	0.8-2.8
3,500	7-21	0.7-2.1	0.7-7.0	3.5-17.5	1.1-3.9
4,500	9-27	0.9-2.7	0.9-9.0	4.5-22.5	1.4-5.0

While the nutrient removal from a single pinestraw raking is not likely to be important to tree nutrition, accumulated removals from repeated harvests could reduce tree growth and pinestraw production, especially if any of these nutrients is initially in short supply. Continuing productivity is not necessarily related to the quantity of nutrients removed. Nitrogen and phosphorus removals generally have the greatest potential to reduce productivity even though more calcium might be removed than nitrogen or phosphorus.

Fertilization and Longleaf Pine

Fertilization shows promise on many sites. It can replace nutrients lost by raking, and it can increase production of needles and wood as well. Because foliage typically remains on pine trees for two growing seasons (approximately 1.5 years), most needles that fall the second year following fertilization actually are produced during the first growing season after fertilization. When fertilized stands are compared to unfertilized stands, longleaf pinestraw dry weight has increased on research plots by as much as 50 percent by the second growing season following application. Increases of 25 to 40 percent are common. Assuming that longleaf fertilizer responses over time are similar to those for loblolly pine, they would be expected to gradually decline over the next four- to five-year period.

Fertilization of longleaf pine has also produced significant responses in tree diameter growth within stands as old as 55 years. On research plots at the North Carolina Sandhills Gamelands, trees have responded to fertilization with a 19 percent increase in diameter growth (compared with unfertilized trees) during the first growing season, and a 49 percent increase (compared with unfertilized trees) during the second growing season.

As described in the section on **Fertilizer Recommendations,** caution must be taken not to overfertilize. Instead, address the trees' nutritional needs to maintain their long-term health and vigor.

Determining Nutrient Needs

Laboratory analyses of both soil and foliage can be used to identify existing and potential crop nutrient deficiencies. The concept of a critical threshold or sufficiency level is commonly applied to nutrient concentrations. Tests that show concentrations above the appropriate sufficiency level indicate sites that most likely will not respond to additional amounts of that particular nutrient. Test results below the sufficiency level indicate the stand will probably respond to nutritional amendment.

Most soil nutrient sufficiency levels for longleaf pine stands are too low for standard agricultural soil tests to be helpful. Phosphorus is the primary exception. The sufficiency level for soil phosphorus for longleaf pine is estimated at 5 ppm (parts per million), which is equivalent to a North Carolina Department of Agriculture soil test P-index value of 5 to 6.

Foliage analysis provides a useful way to determine the nutritional status, needs, and likelihood of response to fertilizer in terms of timber or fiber production. As with soil tests, the concept of sufficiency levels is applied to foliage analysis using plant tissue tests. Based upon previous work with other pine species as well as research results from five longleaf pine plots in North and South Carolina, the following tentative foliar sufficiency levels are suggested (Table 4).

Table 4. *Tentative nutrient sufficiency levels for dormant longleaf pine foliage.*

N	P	K	Ca	Mg
Percent Concentration				
0.95	0.08	0.30	0.10	0.06

*Values are expressed as decimal fractions of 1 percent of sample dry weight.

Although foliage sampling is difficult, and sensitive to handling and treatment, reliable results can be obtained by following a sampling protocol that consists of specific collection, handling, storing, and shipping procedures. The following discussion provides some basic guidelines; however, check with the laboratory that will be handling any plant tissue analysis for a complete sampling protocol before collecting, storing, or sending foliage samples. A list of several plant tissue analysis labs in the Southeast is included in Table 5.

At least one dominant tree should be sampled for every 10 acres, with a minimum of five trees sampled. One primary lateral branch tip from each sample tree should be removed during the dormant season (December through January is best), from the top third of the crown (typically accomplished using a shotgun or rifle). Remove from the branch 50 to a 100 fully mature needles from the first flush of the previous growing season (see Figure 1), and either store under refrigeration or promptly oven-dry at a temperature of 150°F. Proper sample treatment is necessary to prevent continuing biological activity, decomposition, nutrient loss, and dry weight loss.

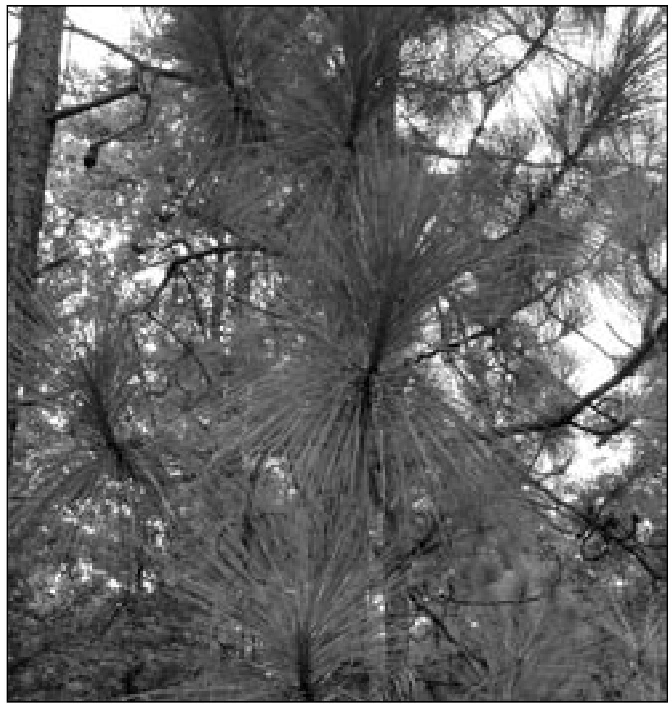

Figure 1. *This photograph of a longleaf pine branch during the dormant season shows two flushes of needles from the previous growing season. The first flush is located further from the branch tip and has slightly longer needles that are more nearly perpendicular to the stem. Flushes (usually two, occasionally three) are separated by a short gap in the foliage along the stem. Foliage samples should be collected during the dormant season (December through January is best), by taking 50 to 100 fully mature needles that represent the first flush of the previous growing season from a primary lateral branch located in the top third of the tree crown.*

Table 5. *Names, addresses, and phones numbers of several plant tissue analysis labs in the Southeast.*

Name	Address	Phone
A&L Agricultural Laboratories	7621 Whitepine Road, Richmond, VA 23234	(804) 743-9401
Harris Company	624 Peach St., P.O. Box 80837, Lincoln, NE 68501	(402) 476-2811
MMI Labs	183 Paradise Blvd., Suite 108, Athens, GA 30607	(706) 548-4557
Plant Advisory Section, Agronomic Division, NCDA	4300 Reedy Creek Road, Raleigh, NC 27607-6465	(919) 733-2656
Waters Agricultural Laboratory	Newton Hwy., P.O. Box 382, Camilla, GA 31730-0382	(229) 336-7216

Fertilizer Recommendations

Productivity of both wood and foliage in longleaf pine may be sustained or enhanced by applying fertilizer. Success requires efficient application of the right amount of the right material at the appropriate time. Unlike most agricultural crops, longleaf pine is a long-lived perennial, and a fertilization strategy must address the long-term health and vigor of the stand as well as short-term productivity gains. Maintenance of a suitable balance of the major nutrients (N, P, K, Ca, and Mg) is critical. An ideal nutrient management program for pinestraw production would include laboratory analysis of foliage samples at approximately six- to seven-year intervals to compare foliar nutrient concentrations with sufficiency levels such as those in Table 4. Remember, over-fertilization can be damaging and costly.

Amount

The maximum recommended single-application fertilization rates for longleaf pine are 100 pounds of N per acre, 60 pounds of P_2O_5 per acre (approximately 25 pounds P per acre), 60 pounds of K_2O per acre (50 pounds K per acre), 100 pounds Ca per acre, and 25 pounds Mg per acre. These rates are adequate to replace nutrients removed over approximately 10 years of unfertilized pinestraw raking. Gains in foliage production and subsequent needle-fall as a result of nutrient additions can be expected to persist for a period of six to seven years following fertilizer application. The rates mentioned above, applied on a six-to seven-year interval, are likely to enhance foliage production and stand growth under conditions of annual raking. Stands raked less frequently (for example, every other year) could be fertilized on a longer cycle.

The amount of fertilizer needed can be determined given the desired amount of each nutrient and the percent of fertilizer material which that element (or a compound containing that element) represents. Commercial fertilizers are required by law to be marked with the percent of dry weight represented by each important nutrient. The three primary nutrients (N, P, K) are listed (in that order) on the label as the percent N, P, 0, and K_2O. Note that the fertilizer label refers to the content of P_2O_5 rather than elemental P (always the second number); and KO rather than K (always the third number). As an example, 100 pounds of 20-5-10 would contain 20 pounds of N (20 percent by weight), 5 pounds of PO, (5 percent by weight), and 10 pounds of KO (10 percent by weight). Whereas calculating the amount of elemental N is straightforward, the amounts of elemental P and K require conversion between elemental weights and compound weights (use Table 6).

Table 6. *Conversions between elemental weights and fertilizer compound weights.*

From	To	Multiply by	From	To	Multiply by
P	P_20_5	2.3	P_20_5	P	0.44
K	K_20	1.2	K_20	K	0.83

Calculate the amount of fertilizer needed to apply a specified amount of a nutrient as follows:

1. Divide the desired elemental rate by its percent composition in the fertilizer material (divided by 100, so it is expressed as a decimal).
2. Convert from element to compound where necessary (such as with P and K).

EXAMPLE

The amount of urea (labeled as 46-0-0, meaning that it contains 46 percent nitrogen by weight) needed to apply 100 pounds of elemental nitrogen per acre would be 100 divided by .46 equals 217 pounds of urea per acre. A more complicated example involving phosphorus expressed as an elemental weight would require conversion. The amount of triple superphosphate (TSP, labeled 0-46-0) needed to apply 25 pounds of elemental phosphorus per acre would first require knowing the amount of P_20_5: 25 (pounds P) times 2.3 (conversion of P to P_20_5): 57.5 pounds P_20_5 The amount of fertilizer material to apply 57.5 pounds of P_20_5 per acre would then be 57.5 divided by .46 (its percent in TSP) equals 125 pounds of TSP per acre.

Calculations involving fertilizer materials that contain more than one element (for example, TSP also contains 14 percent calcium) must be considered carefully when selecting fertilizer materials and determining rates.

Material

Urea and ammonium nitrate are the conventional sources of nitrogen fertilizer for forestry. Ammonium nitrate has a slightly higher potential for nitrate leaching than urea and is frequently more expensive, so urea is more commonly used by the forest industry in the southeastern United States.

Choices among phosphorus sources include soluble superphosphates and ammonium phosphates, as well as more slowly soluble rock phosphates. Tree responses are generally similar for all three sources. Diammonium phosphate (DAP) is widely used for the phosphorus requirement and at least part of the nitrogen when a combination of these two elements is prescribed. When both nitrogen and phosphorus are needed, a single combined application is preferred over separate ones for nutritional as well as operational reasons. Urea can be combined with DAP to achieve higher rates of nitrogen, though mixing can be difficult in high humidity. Ammonium phosphate application can accelerate the competition from understory vegetation, especially in younger stands, because of the additional nitrogen.

Potassium is purchased as muriate of potash. Dolomitic lime provides a source of calcium and magnesium, but it is rarely used for pine species. More frequently these two elements are added as gypsum ($CaSO_4$) and Epsom salts ($MgSO_4$).

Limited information is available concerning the benefits of trace element applications to forest stands. Deficiencies of boron, copper, and manganese have occasionally been identified in loblolly pine. Laboratory determination of foliar micronutrient concentrations should be conducted if a specific deficiency is suspected.

Timing and application

Make fertilizer applications for existing forest stands in the early spring to maximize plant uptake. If care is taken to avoid direct application of fertilizer material to open water, these recommended rates on piedmont and coastal plain forest soils should not result in nitrate or phosphate water-quality problems. Sites should not be burned for six months prior to fertilization to avoid applying urea to an ash layer that may increase ammonia volatilization. Also, fertilized stands should not be burned for several years following treatment to avoid loss of potential pinestraw production and tree growth due to crown scorch.

Fertilization can have other impacts, both positive and negative, besides greater stand productivity and increased production of foliage and needle-fall. Understory vegetation is likely to increase in growth and nutrient concentration, resulting in higher nutritional content and, therefore, improved wildlife habitat. Moisture stress may become a concern due to increased foliage mass, especially on sandy, well-drained sites. This problem could be particularly acute if the amount of fine roots has been reduced by wildfire or even by a hot prescribed burn. Damage from ice and wind could increase in the short term as a result of greater foliage and branch weights, especially in thinned stands. Minimize these risks by delaying fertilization for several years following thinning. High rates of nitrogen fertilizer (especially if nitrogen is applied alone) may also increase the potential for insect and disease damage, particularly that caused by bark beetles and fusiform rust. For more information about application procedures, see the article by H. L. Allen listed under **Additional Reading**).

Does Fertilization Pay?

Forest fertilization has been shown to be economically attractive for some landowners in the Southeast for wood production in loblolly pine. Fertilization of longleaf pine stands on nutrient-limited sites appears likely to generate a reasonable return on investment (ROI) in increased pinestraw production. One key to profitable fertilization is to select those stands most likely to show an adequate response. On appropriate sites, responses to recommended fertilizer applications in the range of 20 to 50 percent (compared to unfertilized needle production rates) have been documented. Sites where factors other than nutrition limit tree growth (extremely dry or wet sites or thin soils, for example) are poor risks. Fertilization cannot eliminate or directly compensate for these limitations.
Cost of treatment and the price of pinestraw are also key variables in the financial analysis of longleaf fertilization, as illustrated in Table 7.

Table 7. *Required longleaf pinestraw fertilization response to obtain a 10 or 20 percent return on investment (ROI). Required response is shown both as the increased number of bales per acre the second year following application, and as a percent response over unfertilized production rates. Shaded values support the example below the table.*

		Straw Response for 10% ROI					**Straw Response for 20% ROI**				
		Added number of bales 2nd year	**Required Response %** Unfertilized production (pounds/acre/year dry)				**Added number of bales 2nd year**	**Required Response %** Unfertilized production (pounds/acre/year dry)			
			2,500	3,125	3,750	4,375		2,500	3,125	3,750	4,375
			(Bales per acre per year)					(Bales per acre per year)			
Cost	**Price per bale**		100	125	150	175		100	125	150	175
$50	$.50	38	38	30	25	22	48	48	38	32	27
	$.75	25	25	20	17	14	32	32	25	21	18
	$1.00	19	19	15	13	11	24	24	19	16	14
	$1.25	15	15	12	10	9	19	19	15	13	11
$100	$.50	75	(75)	(60)	(50)	43	96	(96)	(77)	(64)	(55)
	$.75	50	(50)	40	34	29	64	(64)	51	43	36
	$1.00	38	38	30	25	22	48	48	38	32	27
	$1.25	30	30	24	20	17	38	38	31	26	22

Values in parentheses represent situations in which the required responses do NOT appear reasonable to expect.) Important assumptions made for these calculations are consistent with recommendations in this publication, including:

1. The fertilization treatment is the maximum recommended rate (100 pounds N per acre, 60 pounds P_2O_5 per acre, 60 pounds K_2O per acre, 100 pounds Ca per acre, and 25 pounds Mg per acre).
2. Pinestraw production response (increase) peaks two years after fertilization and declines to zero by year seven.
3. Dry weight per bale is 25 pounds—corresponding to an average fresh bale weight of 30 pounds with a moisture content of 17 percent.
4. Fertilizer costs $50 or $100 per acre, including application cost.
5. Cost of fertilization is expensed during the year applied for tax purposes.
6. Pinestraw "stumpage" prices available to the landowner, net of production costs, are $.50, $.75, $1.00, or $1.25 per bale over the seven-year investment period.
7. The applicable income tax rate is 28 percent.
8. Annual pinestraw production would remain level if not fertilized.

EXAMPLE

Notice the shaded values in Table 7. If fertilization costs $50, a peak response of 19 bales per acre the second year following treatment (compared to unfertilized production levels) would represent a 10 percent return on investment, assuming a market price of $1 per bale. The same 19-bale response can be expressed as a percentage of the base level of production: It would require a 19 percent increase on an area that historically produced 100 bales per acre per year before fertilization; a 15 percent increase on an area producing 125 bales per year, a 13 percent increase on 150 bales per year, and an 11 percent increase on an area already producing 175 bales per year.

The higher the bale price and amount of response and the lower the cost of treatment, the greater the corresponding return on investment. Knowing the amount of response to fertilizer needed to generate an adequate return (for example, 10 percent or 20 percent) could help pinestraw producers (especially those with production records on longleaf stands) decide whether and where to invest in fertilization. Comparing second-year response data from test plots to table values would help producers confirm the financial return on a specific site.

Other Considerations

Research has shown that the nutrient removals associated with pinestraw raking can be physically and economically replaced with fertilization. But other impacts on the ecosystem may not be as easy to remedy. Removal of needles can affect soil moisture, temperature, and microbial populations—particularly if the forest floor is removed down to the mineral soil. Such disturbance could in turn reduce tree growth and pinestraw production by limiting the amount of site resources available to the trees. The vehicle traffic associated with pinestraw removal can compact the soil, resulting in reduced ability to absorb rainfall and increased potential for drought stress on dry sites or flooding on wet sites. Understory vegetation is sometimes removed to obtain straw free of debris, resulting in a decrease in species diversity that may affect wildlife habitat suitability. Landowners can minimize negative impacts by:

- Leaving some organic layer covering the mineral soil.
- Raking sites only during dry conditions to minimize soil compaction.
- Avoiding sites with unusual understory plant diversity—especially sites containing rare and endangered plants.

Additional Reading

Allen, H.L. 1987. Forest fertilizers: Nutrient amendments, stand productivity, and environmental impact. *Journal of Forestry.* 85(2):37-46.

Morris, L.A., E.J. Jokela, and J.B. O'Conner Jr. 1992. *Silvicultural guidelines for pinestraw management in the southeastern United States.* Georgia Forest Research Paper No. 88, Georgia Forestry Commission, University of Georgia, Athens, Ga.

Recommendations for the use of agricultural chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the North Carolina Cooperative Extension Service nor discrimination against similar products or services not mentioned. Individuals who use agricultural chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage regulations and examine a current product label before applying any chemical. For assistance, contact your county Cooperative Extension agent.

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