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FOR327

Guide to Fertilization for Pine Straw Production on Coastal Plain Sites[1]

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Introduction

Pine straw has gained popularity as a mulch in residential and commercial landscaping with increased interest in natural landscaping in urban and suburban areas. It is attractive, relatively low-cost, easy to work with, and suitable for various locations, including slopes. It plays an important role in water-efficient landscaping (xeriscaping) as water becomes an increasingly limited resource. In Florida, pine straw raking is a relatively new enterprise, but by 2005 it had become an important industry, with an output similar to the value of pulpwood (Hodges et al. 2005).

Longleaf and slash pines are the favored southern pine species because their long needles bale well. However, loblolly plantations can be raked when demand is not met by the preferred species. Pine straw raking may begin when stands are as young as seven or eight years old, when pine straw yield is expected to be between 100 and 150 bales per acre. Trees yield the most pine straw at the age of about fifteen years, potentially producing between 200 and 300 bales per acre, depending on site quality, pine species, and management intensity (Duryea 2009).

The Importance of Pine Straw in Pine Stands and Potential Consequences of Its Removal

Pine straw is the uppermost layer of forest floor consisting of recently fallen pine needles that have not yet decayed. Pine needles fall year-round with the peak fall in southern pines occurring late in the growing season and early winter, two years after the needles are produced. Not only is it aesthetically pleasing, pine straw used as mulch in landscaping has the same positive effect on plant growth that it has in the forest. The layer of pine needles, fresh and at various stages of decomposition, has many important functions in the forest, affecting its productivity.

- Pine straw plays an important role in nutrient cycling because as the needles decompose, the nutrients revert to available forms (available meaning that they can be absorbed by plant roots again) in a process called mineralization (Jorgensen and Wells 1986, Switzer and Nelson 1972).
- After mineralization by soil fungi, bacteria, insects, and earthworms, pine straw contributes organic matter to the soil and improves its nutrient- and water-holding capacity.
- Pine straw reduces evaporative water loss from the soil surface, and it has great water-holding capacity, two

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qualities that help ensure that pine trees have the water they need to grow.

- Pine straw helps insulate the soil from temperature extremes and reduces the rate of moisture and temperature change.
- It reduces erosion and weed growth
- Pine straw provides habitat and food for many animals and microorganisms that are important to the forest ecosystem because they contribute to litter decomposition or are a source of food for many wild life species (Ober and deGroote 2014).

Figure 1. Forest floor with a natural layer of pine straw (back) and after pine straw harvest (front)
Credits: Anna Osiecka, University of Florida

Because of these benefits, repeated annual removal of pine straw for extended periods, such as the current practice of raking successive short (12–20 year) pine stand rotations, may have detrimental effects on forest stands and soil productivity. Evidence suggests that excessive raking may cause a series of problems: nutrient deficiency, especially on infertile sites (Blevins et al. 2005, Morris et al. 1992, Ogden and Morris 2004); increased tree water stress, especially on dry sites (Ginter et al. 1979, McLeod et al. 1979); increased erosion; decreased soil organic matter content; increased soil bulk density (Haywood et al. 1998); change in microbial and animal populations (Ober and DeGroote 2011, 2014); and decreased plant diversity due to understory vegetation removal. Mineral fertilization can compensate for nutrient removal, but not for all of the other losses associated with excessive harvesting of pine straw. Some of the harmful effects (reduced site fertility, for instance) may be ameliorated with additional fertilization to maintain or increase straw yields, but increasing inputs of fertilizer will not solve the entire problem; site-specific management and sustainable raking frequencies are also needed.

Nutrient removals vary greatly from site to site, largely depending on those factors determining the amount of pine straw harvested, such as stand age, species, site fertility, pine basal area, proportion of the stand being harvested, timing of harvest, and raking efficiency. Based on survey results of commercial pine straw operations in Georgia, Morris et al. (1992) reported the following ranges of nutrient removal (lb/acre) during a single raking of various stand types and species: nitrogen (N) 5–60, phosphorus (P) 0.2–4.8, potassium (K) 0.4–2.9, calcium (Ca) 3–21, and magnesium (Mg) 0.6–5.0. Potential removal of nutrients is greater with loblolly than with slash or longleaf pine straw because of greater yield, greater nutrient requirements, and foliage nutrient concentration, as well as generally higher fertility of sites on which loblolly is usually planted. Small K removals can be attributed at least in part to rainfall leaching this nutrient from needles before pine straw harvest (Duffey and Schreiber 1990). Even though nutrient removals are relatively small for a single harvest, they become significant if a stand is raked repeatedly. According to Morris et al. (1992), if an "average" slash pine stand is raked annually between ages 10 and 22 years, nutrient removals associated with pine straw harvest exceed those calculated for complete above-ground harvest of all trees. Removals of Ca and Mg with pine straw are about equal to those in merchantable stem harvesting, but N, P, and K removals from pine-straw harvests are two- to four-fold greater than N, P, and K removals from complete above-ground harvests because those nutrients are concentrated in the foliage (Neary et al. 1984). Disturbing the nutrient cycle by removing pine straw may result in reduced tree growth (McLeod et al. 1979) and, ultimately, diminished pine straw production.

Fertilization Practices in Pine Straw Production in North Florida

Chevasco and Minogue (2012) summarized survey responses from pine straw producers in 21 north Florida counties, representing 32,214 raked acres. Slash pine was by far the most common raked species and was dominant in the stand on 89% of surveyed acres. Half of the responders were using fertilizers for pine straw production. Fertilizers were typically applied to supply N, P, and sometimes K in the spring (54% of responders), but also during the fall (18%) and winter (28%). Among surveyed producers, 50% preferred to hire a contractor for application, and fertilizers

were applied with a tractor or by helicopter (72 and 28% of the responders, respectively). In addition to common fertilizers (i.e. diammonium phosphate, urea, ammonium nitrate, and muriate of potash), commercial blends (N:P:K ratios 10-10-10, 13-13-13 or 17-17-17) were also mentioned in the responses. Many specific fertilizer rates were reported by growers in the survey. Among those fertilizing, 67% noticed increased straw yields with fertilization, and 69% of the responders were interested in learning more about fertilization.

Determining a Need for Fertilization

Fertilization using mineral or organic sources can replace removed nutrients, and organic fertilization (manures) can additionally have a positive effect on soil organic matter content. Fertilization has been shown to increase pine straw production in most, but not all cases. According to Dickens et al. (2014), fertilizing with primary macronutrients N, P, and K and, to a lesser extent, with secondary macronutrients Mg and Ca, and the micronutrients manganese (Mn), boron (B), and copper (Cu) can improve pine straw and wood yields on low-fertility sites and harvested (cut-over) forest sites. However, NPK fertilization has generally shown no positive effect on pine straw yield beyond one year on highly fertile sites, including most old fields with good nutrient- and water-holding capacities. According to Jokela and Long (2012), excessively drained deep sands with little soil profile development, which occur in north Florida sandhills and similar areas in the Southeast (CRIFF G-group soils), are not well-suited for mineral fertilization because water deficits generally limit responses to silvicultural treatment. These soils require management practices that conserve organic matter.

To determine the need for and potential benefits from fertilization, and to develop biologically and economically sound fertilization prescriptions, several factors must be considered, such as stand age and development, stocking, pine species, soil characteristics, past site cultivation history (including fertilizations), raking frequency and duration, pine straw yield obtained and desired, additional management goals, and disease incidence, especially fusiform rust and pitch canker. Additionally, four diagnostic tools are available and may be used individually or collectively to improve the effectiveness of fertilization:

- soil series and profile characteristics
- soil sampling
- foliar sampling
- leaf area index (LAI)

The soil series and profile characteristics are the most easily applied diagnostic tools to guide fertilizer recommendations (Jokela and Long 2012). Soil series maps are now available on the Natural Resources and Conservation Service (NRCS) Web Soil Survey website. This tool can be used to delineate the stand and show soil series and other soil information for the area in question. The soil survey information is also available in mobile form through the SoilWeb app, which can be downloaded for both Android and iPhone users. A web-based EDIS publication by Jokela and Long (2012) lists soil series of the southeastern Coastal Plain region and classifies them into eight groups (A–H) established by the Cooperative Research in Forest Fertilization (CRIFF) program based on soil texture, depth of the subsurface soil layers, and soil drainage. Additionally, plant indicator species are provided for assessing soil drainage classes. The authors give general recommendations for young and established stands within each CRIFF forest soil group. More specific recommendations are possible using the diagnostic tools described below. Assistance with using these diagnostic tools and other helpful information is available from your local UF/IFAS Extension office.

Soil sampling should be done before the first raking to obtain baseline nutrient information (Moorhead and Dickens 2005), and soil samples can be collected any time of year (Dickens et al. 2004, 2010). Dickens et al. (2010) describe the proper method for soil sampling and analysis in southern pine stands. Soil samples should be collected at 0- to 6-inch depth from several mapped locations per stand. Ideally, there should be at least three composite samples per 20- to 40-acre stand, each consisting of eight to ten approximately 1-inch-diameter soil cores. If there are distinctly different soil types within the sampling unit, a separate composite sample must be collected for each soil type. If both soil and foliage samples are being collected, they should represent the same management unit areas (Wells and Allen 1985).

While soil nutrient concentration is a basic criterion for determining fertilization needs for row crops, it provides only limited information for making forest fertilization decisions (Moorhead and Dickens 2005, Wells and Allen 1985), because trees do not have to meet their nutritional needs during a few months of a single growing season. Soil analyses results can help to determine stand phosphorus needs (Dickens et al. 2004, 2010). However, according to Wells and Allen (1985), while high P concentrations indicate phosphatic or highly fertilized soils and rule out the need for fertilization, low P concentrations do not necessarily indicate the need for added phosphorus. In spite

of these limitations, comparing soil analyses results with the published critical ranges can provide some guidance in determining fertilization needs. It is important to compare the numbers for the same soil depth and the same extraction method. According to Dickens et al. (2003b), critical ranges for soil P are 3 to 8 ppm in loblolly, longleaf, and slash pine, depending on the extraction method.

Foliar sampling is used to determine nutrient availability by measuring what the trees have actually absorbed. This method is considered the best diagnostic tool to predict response to fertilization in pine stands. The frequency of foliage sampling should be adjusted, depending on the intensity of pine straw harvesting (Morris et al. 1992). When pine straw is removed only three times during the rotation, a single baseline foliar analysis prior to mid-rotation fertilization is sufficient. Plantations raked annually from an early age require foliar sampling approximately every five years, starting before the first straw harvest. According to Moorhead and Dickens (2005), in intensively raked plantations, annual to biennial monitoring of foliar nutrient status may help to detect and remediate nutrient deficiencies early.

Foliage should be collected from six to 15 dominant and co-dominant trees (the tallest) per stand (Dickens and Moorhead 2005, Morris et al. 1992, Wells and Allen 1985). Blevins et al. (2005) recommend sampling a minimum of five trees for every 10 acres. However, a separate composite sample from several trees is needed for each unit area with different soil or stand growth characteristics (Wells and Allen 1985). A representative composite sample should consist of at least 200 needle clusters (called fascicles) that are free of soil and other contaminants, as well as disease or insect damage.

Foliar sampling must follow the standard procedure to ensure that laboratory results accurately represent the nutrient status of the sampled stand. Dickens and Moorhead (2005) provide a good description and photographs to illustrate the correct sampling method. Needle samples should be collected during dormant season, after hardening off and before spring bud break (in north Florida usually from late December to early February). Needles are taken from the first flush of the past season's growth on the primary lateral branches in the upper ⅓ to ½ of the crown on the south side. The crown should be free of competition for light at the point of collection. Samples must be stored under refrigeration or promptly oven dried at 140˚F (60˚C) to prevent continuing biological activity, nutrient loss, and decomposition. Some analytical laboratories accept fresh or dry foliage, while others require dried and ground foliar tissue.

Foliar samples should be analyzed for N, P, K, Ca, and Mg (Morris et al. 1992). According to Dickens et al. (2004) foliar analysis results give an indication of fertilizer need for P and K, and for less frequently applied nutrients such as Ca, Mg, S, Mn, B, and Cu. Foliar nitrogen concentration should also be compared to the published critical concentration for the species in question, although foliar N is not as reliable as leaf-area index (LAI) in predicting the response to N fertilization. The critical level concept assumes that the stand will respond to an added nutrient when foliar concentration falls below an established critical concentration (Jokela 2004). Even though several authors have published critical (minimum) values or ranges of nutrient concentrations in pine foliage, these numbers are not known with precision, and therefore should be used as qualitative guides along with other criteria (Jokela 2004). Some of these critical values have been summarized by Dickens and Moorhead (2005) in Table 1. In another publication, the same authors (Moorhead and Dickens 2002) quote slightly wider critical ranges for slash pine.

Foliar or soil samples can be submitted for analyses to commercial or state government laboratories (consult your local UF/IFAS Extension office for guidance). Florida landowners can send their samples to the UF/IFAS Extension Soil Testing Laboratory (ESTL) and should visit the ESTL website for instructions, pricing, and submission forms. For tissue samples use Plant Tissue Test submission form SL131. For basic soil analyses (pH, organic matter, and Mehlich-3 extractable P, K, Mg, and Ca) use Pine Nursery Soil Test Form SL132. If you want to request soil micronutrients or other tests use Producer Soil Test Form SL135 with the Crop Code 600. Since ESTL does not provide interpretation of forestry soils or pine tissue analyses results, landowners should seek assistance of an appropriate UF/IFAS Extension Agent, County Forester, or commercial consultant for interpretation of the analyses results and fertilization recommendations based on these results.

Leaf area index (LAI) is considered the best indicator of stand nitrogen needs (Dickens et al. 2004) because N is directly involved in crown building. LAI is the projected leaf (needle) surface area per unit of ground area. The most practical indirect methods of estimating leaf area index are based on light transmission or reflectance (Baldocchi 2012) and require the use of specialized equipment. LAI should be determined in summer at peak leaf area from a minimum 10 sample points in a typical 40-acre stand. LAI estimates should be made under individual trees if basal area (BA) is below 80 ft^2/acre or between rows of trees if BA is greater than 80 ft^2/acre.

Fertilization Recommendations

According to Morris et al. (1992), fertilization is recommended for raked stands growing on cut-over sites because in most cases it increases tree growth and pine straw production and, without fertilization, stand growth may decline. Old-field sites in the Middle and Upper Coastal Plain are inherently the most fertile and often contain reserves of P, K, and Ca resulting from past agricultural fertilizations. Nitrogen may be the only limiting nutrient in these cases. Cut-over sites have lower reserves of N, P, and K compared to old-field sites in the same area. Flatwood sites of the Lower Coastal Plain are inherently less fertile than Middle and Upper Coastal Plain sites. Besides low macronutrient reserves, some flatwoods may also exhibit micronutrient deficiencies (Jokela et al. 1991b). Flatwood sites with an underlying argillic (clay) horizon have a greater nutrient-holding capacity than the ones lacking an argillic horizon. Sandy upland sites with little organic matter, such as the sandhills occupying large areas in the central Florida peninsula and eastern panhandle, are most nutrient deficient and have the lowest capacity to retain added nutrients. Organic fertilizer materials such as poultry litter, with typically ⅔ of total N in the organic form, may be the most beneficial form of fertilizer on these excessively drained poor soils.

Fertilization recommendations for pine straw production are similar to those for other management objectives and include application of N, P, and K. Other nutrients may be added if there is a demonstrated or suspected deficiency. Morris et al. (1992) provide specific fertilization recommendations for old-field or cut-over sites, different stand ages, raking frequencies, and various site types, but they do not recommend fertilization for sandhill sites characterized by soils with a sandy surface horizon greater than 40 inches deep or those without fine-textured subsoil. (A *horizon* is a layer of soil whose physical characteristics differ from the layers above and beneath.) Dickens et al. (2004) provide species-specific recommendations. Among the three southern pine species raked for straw, longleaf is the least nutrient-demanding, loblolly the most demanding, and slash pine intermediate in nutrient requirements and fertilization response. These differences are reflected in nitrogen rate recommendations in particular. The need for P and K fertilization (typically 20–50 lb P and 50–80 lb K per acre for all three species in the Coastal Plain) is best indicated by foliar analyses.

Morris et al. (1992) identified two general fertilization regimes on sites that have been deemed to be nutrient deficient.

1. Young pine plantations raked annually beginning at or near crown closure (about 8 years of age) require repeated fertilizations (approximately every five years), beginning around crown closure.

2. Established pine stands with a different management objective, where pine straw is a by-product harvested two to three times during the rotation after the crown closure (between 8 and 12 years of age) should be fertilized once during mid-rotation.

Their recommendations, combined with a later, species-specific guide by Dickens et al. (2004) and recently updated by Dickens (personal communication 2015), can be summarized as follows:

1. For young plantations on any site (except for sandhills) that are raked annually beginning at crown closure, apply 200 lb N/acre (loblolly and slash only) at age 6, 11, and 16 years and 20 to 50 lb P/acre with the initial fertilization at 6 years. Nitrogen rate must be lower for longleaf pine to avoid excessive growth rates, which may result in weakened trees and which sometimes cause irreversible leaning of young trees (Dickens personal communication, 2015). He recommends 75 lb N/acre when diameter at breast height (dbh) is less than 6” and 125 lb N/acre for stands with an average dbh of 6” or greater. Potassium should be included in the first fertilization of flatwood sites (80 lb K/acre) and cut-over sites of the Upper and Middle Coastal Plain Uplands with loamy to sandy surface soils 20 to 40 inches deep (50 lb K/acre), but potassium is usually not necessary if fine loamy to clay-textured horizons are less than 20 inches from the surface, or on old-field sites.

2. Established flatwood stands, typically raked twice during the rotation following one mid-rotation fertilization, should receive 200 lb N (loblolly), 150 lb N (slash) or 125 lb N (longleaf stands with an average dbh ≥ 6”) , and 20 to 50 lb P per acre. Established stands in the Upper and Middle Coastal Plain Uplands, which are typically raked two to three times during the rotation after mid-rotation fertilization, should receive 200 lb N (loblolly), 150–175 lb N (slash), or 125 lb N (longleaf stands with dbh ≥ 6”), 20 to 50 lb P, and 50 lb K per acre at mid-rotation (8 to 12 years).

Fertilizer Materials

Fertilizer materials used in silviculture, regardless of the management objective, are less varied than those used in

agriculture. The most widely used NPK fertilizers for pine straw production are listed in Table 2.

Urea is the most frequently used nitrogen fertilizer in southern pine silviculture because of its high N concentration and competitive price. However, as urea degrades, it releases ammonium (NH_4^+) ions and ammonia gas (NH_3). Ammonia is subject to volatile losses, which have been observed to be between 3% and more than 50% during measurement periods that range from 14 to 60 days following silvicultural fertilization (Elliot and Fox 2014, Zerpa and Fox 2011). Greatest N loss through ammonia volatilization occurs following urea applications at high temperatures and without incorporation, especially in high-pH soils (Overdahl et al. 2014). Cut-over sites that have been in pines for more than one rotation usually have acidic soils with pH ranging from the low 4s to the mid-5s. Coated urea materials have been developed to mitigate this problem by allowing gradual release of urea in a controlled fashion. Polymer-coated (PCU) products are superior to sulfur-coated urea (SCU) but more expensive. Combination products typically consist of urea coated with thin layers of sulfur and polymers and are less-expensive alternatives to PCUs. We are currently testing a PCU product to determine the feasibility of using it in pine straw production in a long-term study supported by the Florida Department of Environmental Protection 319 funding. Pines use controlled-release fertilizers more efficiently, which may mean that using these fertilizers will reduce the potential for groundwater contamination from pine plantations. Volatile losses with ammonium nitrate fertilizer are less than with urea, but nitrate leaching losses can be substantial on coarse textured soils. When ammonium nitrate and other nitrogen fertilizers are applied to poorly drained, anaerobic soils, denitrification and N_2 gas losses can occur (Dickens et al. 2003c).

Triple superphosphate (and other super phosphates) or ground phosphate rock can be used when only phosphorus is needed, or they may be combined with other fertilizers such as urea to supply N and P. When both N and P are required, diammonium phosphate (DAP) and monoammonium phosphate (MAP) are economical choices for supplying both nutrients in a single material. Muriate of potash is the most common potassium fertilizer, but potassium sulfate and potassium nitrate are also being used. Epsom salt (magnesium sulfate, $MgSO_4 \cdot 7H_2O$) containing 9% Mg can be applied to provide magnesium. Gypsum (calcium sulfate, $CaSO_4 \cdot 2H_2O$) containing 23% Ca is a good source of calcium and can alleviate aluminum toxicity in soils with acidic subsoils (Anonymous 2014). In contrast to limestone, gypsum does not increase soil pH. Both Epsom salt and gypsum additionally supply sulfur. Naturally occurring langbeinite, $K_2SO_4 \cdot 2MgSO_4$, often sold as K-Mag®, contains approximately 22% K_2O, 11% Mg, and 22% S. Micronutrient fertilizers, such as copper (Cu), boron (B), zinc (Zn), and Manganese (Mn), can be formulated as simple salts, silicate compounds, or organic compounds. If multiple nutrients are needed, various materials can be blended and applied together.

Usually phosphorus and potassium fertilizer analyses are expressed as the percentage of P_2O_5 and K_2O, respectively, but most rate recommendations refer to elemental amounts of P and K. Multiply P by 2.3 to convert to P_2O_5 and K by 1.2 to convert to K_2O.

Poultry litter may be an economical alternative to mineral fertilizers for pine plantations located in close proximity to poultry farms. In addition to N and P, poultry litter provides other macro- and micronutrients, especially Cu and Zn in a single application (Dickens et al. 2003a). It also adds organic matter to the site, increasing soil moisture-holding capacity. However, in order to achieve the required nutrient goals, poultry litter has to be applied in very large quantities. Therefore, hauling distance, equipment availability, labor costs, and time constraints may become factors limiting its use. Additionally, nutrient concentration may vary greatly depending on the source of poultry litter. Nutrient concentration should be determined for each litter batch in order to apply the appropriate rate. Samples from the state of Florida can be submitted to the Livestock Waste Testing Laboratory (LWTL) in Gainesville using crop code 51 (pine trees) and the appropriate sample and application codes on the Livestock Waste Test Form SL397.

The pine straw yield response to a single poultry litter application is usually significant and long-lasting except on excessively drained deep sands of the sandhills region, where it may last only two to three years (Dickens et al. 2012). To enhance pine-straw production, applications can be made every four to eight years. Even though excessive use of poultry litter may result in nutrients leaching into the groundwater, according to Dickens et al. (2003a), one-time or periodic (every four to eight years) application of up to 8 tons per acre should not pose a threat to groundwater. The authors provide a lot of useful information, including worksheets, to help the landowners make sound decisions regarding fertilizing pines with poultry litter. Do not over-apply poultry litter to loblolly or slash stands, and especially young longleaf pine stands. An analysis of the litter to determine organic-N, ammonium-N and nitrate-N per wet ton of material is essential to avoid exceeding the nitrogen

application rate limits for pine species and weakening trees or causing irreversible leaning in young trees.

Application Method and Timing

Fertilizers can be applied with aerial or ground equipment; the optimum choice depends on plantation size, location, accessibility, equipment availability, costs, and timing of operations. Tractor-mounted fertilizer spreaders can be used on easily accessible sites, while rubber-tired logging skidders equipped with fertilizer spreaders or aerial application systems (usually helicopter) may be necessary in rough or wet areas (Jokela 2004). Poultry litter application requires use of a manure spreader. Research indicates that broadcast and banded fertilizer applications produce similar growth responses (Morris et al. 1992). Broadcast involves spreading fertilizer in swaths across the entire stand, while banding usually limits fertilizer application to a 3- to 4-ft band on or adjacent to the row, and is easier to do when trees are small. Regardless of the method, it is very important to control application rate and uniformity in order to avoid excessive fertilization or concentrated placement. Uniformity is particularly important for micronutrients, which are usually added at low rates (Jokela 2004).

Figure 2. Mineral fertilizer application with a centrifugal fertilizer spreader. Note the cage on the tractor and the cover on the spreader, especially useful in younger stands.
Credits: Anna Osiecka, University of Florida

In the South, fertilizer applications are typically made in late January to early February (Gordon 2012) or in early spring to maximize plant uptake (Anonymous 2011). However, Blazier et al. (2006) found that summer and fall applications of urea formulations resulted in the highest N accumulation and use efficiency in 3-yr-old loblolly pine stands. Fertilization timing in a particular stand is determined by equipment and labor availability, as well as other operations on the site, and should not take place shortly before raking to avoid fertilizer removal. It also depends on the material used. While urea should be applied during cool winter months to minimize volatilization (Dickens et al. 2003c), poultry litter can be spread year-around (Dickens et al. 2003a). Producers can hire contractors to do fertilization and often fertilizer suppliers provide this service.

Figure 3. Poultry litter application with the manure spreader
Credits: Anna Osiecka, University of Florida

Figure 4. Local COOP may supply fertilizer materials, blend custom mixes, and apply fertilizers with the use of specialized equipment
Credits: Anna Osiecka, University of Florida

Best Management Practices (BMPs) for Silvicultural Fertilizers

Existing Florida silvicultural fertilization BMPs (Anonymous 2008) recommend developing a nutrient management plan based on soil, water, plant tissue, and organic material sample analysis with consideration of expected or desired timber and pine straw yields to supply nutrient inputs efficiently. The goal is to capture the benefit of fertilization in improved stand productivity, and to avoid excessive fertilization, which is a threat to water resources. Following are BMPs for silvicultural fertilizations:

- Do not apply fertilizer or locate fertilizer transfer/loading areas within the Primary Zone of the Special Management Zone (SMZ).

- Whenever practical, apply fertilizer to maximize the uptake of nutrients to avoid nutrients moving off-site. Consider use of slow-release fertilizer.
- Do not exceed the maximum amounts of nutrients specified by BMPs:
  - Elemental Nitrogen:
    - No more than 1000 lb/acre over any 20-year period
    - No more than 250 lb/acre for any 3-year period
    - No more than 80 lb/acre during the first two years after planting
  - Elemental Phosphorus:
    - No more than 250 lb/acre over any 20-year period
    - No more than 80 lb/acre over any 3-year period

Potential Negative Effects of Fertilization

Fertilization can stimulate growth of undesirable understory vegetation, which negatively impacts the "rakeable" area and straw yields (Ogden and Morris 2004). Therefore, fertilizer applications must be coupled with a site-specific vegetation management program. Establishment of grasses, forbs, vines, and those shrub and hardwood species dispersed by seed is enhanced by pine straw removal because the mineral soil is exposed to provide a favorable seedbed.

Rowan (1977) showed that NPK plus Fe fertilization increased susceptibility of slash and loblolly pine seedlings to fusiform rust. According to several authors (Dinus and Schmidtling 1971, Hollis et al. 1975), the incidence and severity of some pine diseases, such as pitch canker and fusiform rust, increase with fertilization and intensive stand management. If a stand already has a high incidence of stem fusiform cankers (>25% for slash and >30% for loblolly), nitrogen fertilizer should be split-applied over 2 to 3 years to minimize stem breakage (Dickens et al. 2003c), or the stand should be thinned before it is fertilized. According to Ogden and Morris (2004), fertilization and raking should be avoided in slash pine stands with greater than 25% fusiform rust incidence. Dickens et al. (2004) advise against fertilizing stands when the risk of annosus root rot is moderate to high or where pitch canker is prevalent in the stand. High rates of nitrogen fertilizer may also increase potential for insect damage, especially by bark beetles (Blevins et al. 2005). Lopez-Zamora et al. (2001) observed greater pitch canker and fusiform rust incidence and, as a result, greater slash pine mortality in fertilized compared to non-fertilized plots. Fertilization may also increase pine mortality in stands with high basal area (density) as the pines compete with each other (Glover and Hool 1979, Ogden and Morris 2004), so fertilizers are often applied after thinning or where pine canopies have room to expand. According to Ogden and Morris (2004), NPK fertilization resulted in a two-fold mortality increase in a slash pine stand with high basal area (105 ft^2 per acre at 716 trees per acre), in both raked and non-raked plots.

As mentioned above, fertilization potentially creates risk of contaminating surface- and groundwater. Fertilization rate and timing must be adjusted to soil and pine stand conditions to minimize the movement of nutrients off-site.

To Fertilize or Not to Fertilize?

This is the ultimate question that each pine straw producer has to answer after carefully analyzing potential fertilization benefits and costs, taking into account pine straw and fertilizer prices, and long-term management objectives for a particular stand. Analyzing results of ten studies, Dickens et al. (2012) discussed examples of loblolly, longleaf, and slash-pine sites where net pine straw incomes for NP or NPK treatments were less than for non-fertilized treatments, in spite of greater yields in most cases. Based on these studies, they concluded that a single dose of NP or NPK or a split dose of NPK fertilization on highly fertile old-field sites was generally not profitable at the 2010 prices. This might be partly a result of significant fertilizer cost increases in recent years. A few years earlier, Blevins et al. (2005) suggested that fertilizing longleaf pine stands on nutrient-limited sites can generate a reasonable return on investment. Economic analysis is beyond the scope of this publication, but the take-home message is that selecting a responsive site is a necessary, but not sufficient condition for profitable fertilization. A detailed economic discussion of pine straw production, including fertilization, can be found in two recent publications by Dickens et al. (2011, 2012).

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Table 1. Foliar nutrient concentration critical levels (minimum sufficiency) guidelines for loblolly, longleaf, and slash pines from Dickens and Moorhead (2005)

Nutrient	Loblolly pine[a]	Longleaf pine[b]	Slash pine[a]
	percent dry weight		
Nitrogen (N)	1.20	0.95	1.00
Phosphorus (P)	0.12	0.08	0.09
Potassium (K)	0.30	0.30	0.25 – 0.30
Calcium (Ca)	0.15	0.10	0.08 – 0.12
Magnesium (Mg)	0.08	0.06	0.06
Sulfur (S)	0.10	--	0.08
	parts per million (ppm)		
Boron (B)	4–8	--	4–8
Copper (Cu)	2–3	--	1.5–3
Iron (Fe)	20–40	--	15–35
Manganese (Mn)	20–40	--	20–40
Zinc (Zn)	10–20	--	10–20

[a]Allen (1987); Jokela (2004); Pritchett and Comerford (1983); Wells et al. (1973)
[b]Blevins et al. (2005)

Table 2. NPK fertilizers for pine straw production

Nutrient	Fertilizer	Symbol	Chemical formula	Typical analyses N-P_2O_5-K_2O	Typical analyses N-P-K	Availbility[1] (0–3)	Approximate price/ton[2]
Nitrogen (N)	Urea		$CO(NH_2)_2$	46-0-0	46-0-0	3	$640
	Ammonium nitrate		NH_4NO_3	34-0-0	34-0-0	3	$720
Phosphorus (P)	Triple superphosphate	TSP	$Ca(H_2PO_4)_2 \cdot H_2O$	0-45-0	0-20-0	2	$850
	Ground phosphate rock	GPR		varies[3]		1	$410
Potassium (K)	Muriate of potash	MOP	KCl	0-0-60	0-0-50	3	$570
	Potassium sulfate		K_2SO_4	0-0-52	0-0-43	2	$1,250
N+P	Diammonium phosphate	DAP	$(NH_4)_2HPO_4$	18-46-0[4]	18-20-0	3	$710
	Monoammonium phosphate	MAP	$NH_4H_2PO_4$	11-52-0[4]	11-23-0	2	$700
N+K	Potassium nitrate		KNO_3	13-0-46	13-0-38		
P+K	Monopotassium phosphate	MKP	KH_2PO_4	0-52-34	0-23-28	1	

[1]Availbility (based on vendor's survey): 0=not available, 1=difficult to find, 2=available, but not all the time, 3=readily available
[2]Note that fertilizer prices vary in time as well as by location and market conditions. Reported values are 2014 prices rounded up to the nearest $10 (based on the vendor's survey), and are intended only to provide an estimate of relative costs.
[3]The material available in the Southeast contains 30-33% P_2O_5 (13-14% P).
[4]Analysis may vary